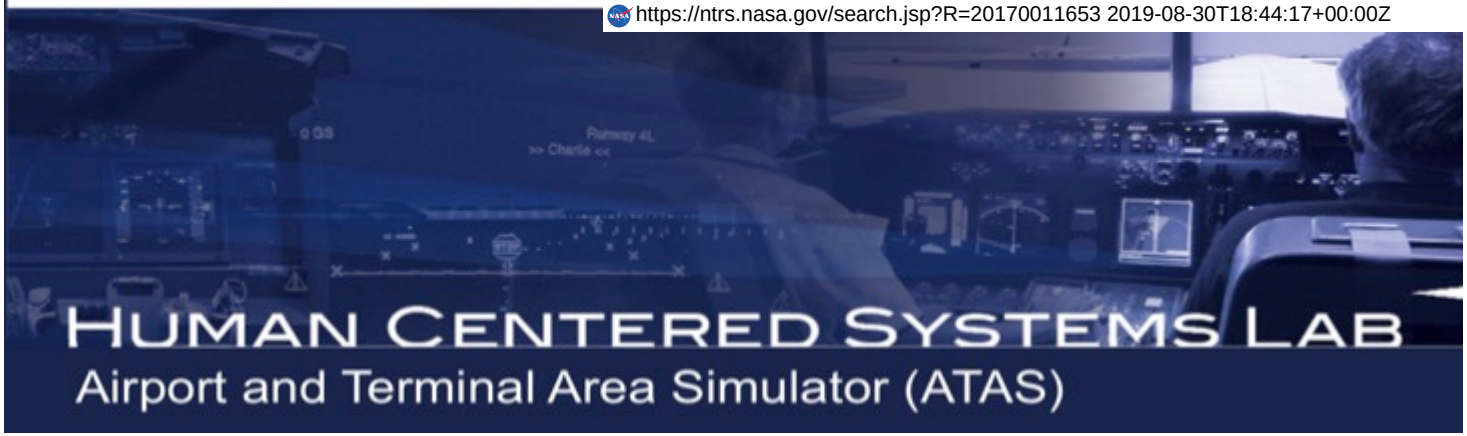
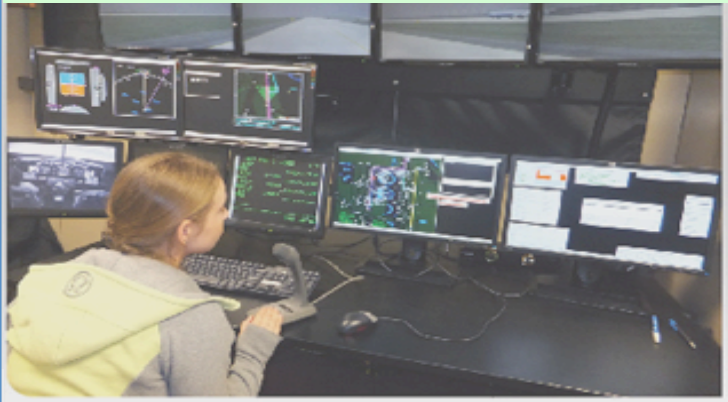


NASA Ames Research Center

NASA/DLR Collaboration
NASA Ames Research Center
22 Aug 2017 – 24 Aug 2017

Flight Deck Surface Trajectory-Based Operations

David C. Foyle, Becky L. Hooey, NASA Ames Research Center
Deborah L. Bakowski, San Jose State University / NASA Ames



POCs:
David.Foyle@nasa.gov
Becky.L.Hooey@nasa.gov
Debi.Bakowski@nasa.gov

Human Systems integration division

URL: http://humansystems.arc.nasa.gov/groups/HCSL

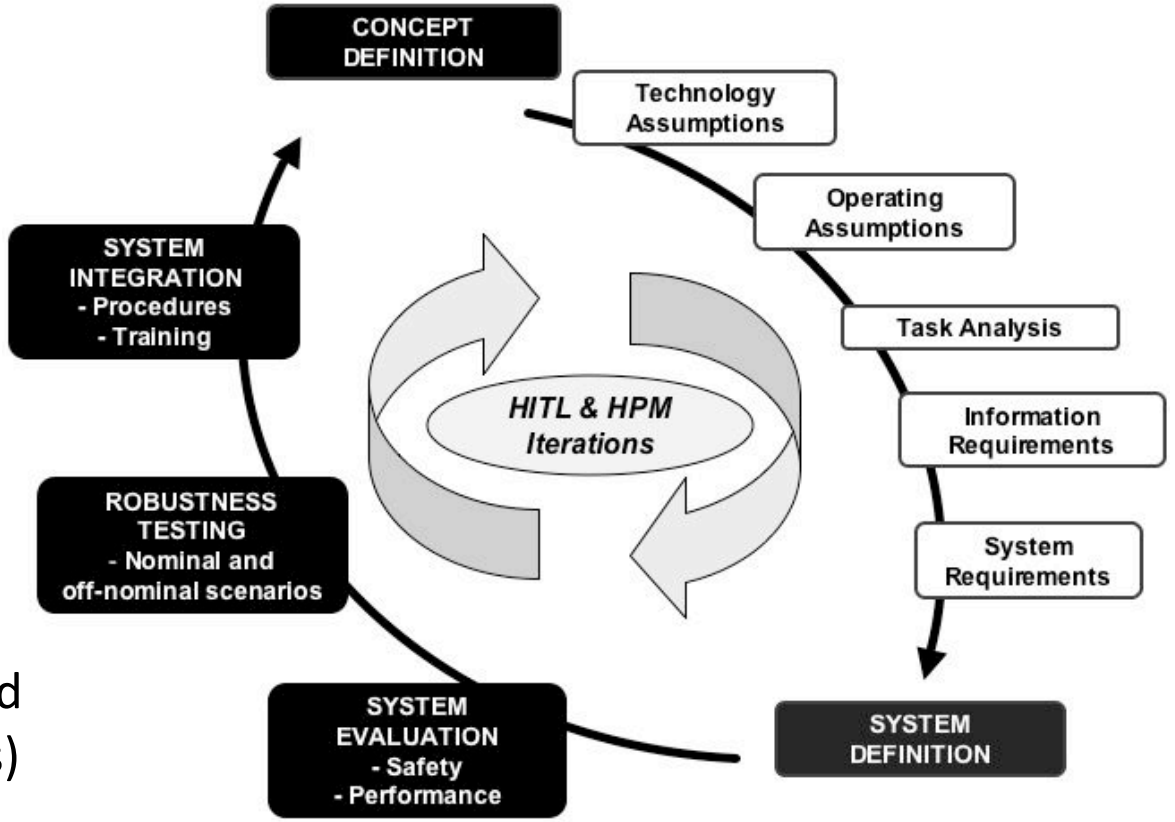
Mission:

- Develop **principled and robust procedures** and **user interfaces** with appropriate **human-automation function allocation**

- Develop **safe and efficient systems** that minimize pilots' cognitive/visual **workload** and increase **situation awareness**

Research Focus Areas:

- Flight Deck Human Factors
- NextGen surface operations and departure concepts (25+ years)
- KCLT ATD-2 Integrated Arrival, Departure & Surface (IADS) demonstration project



Human Systems integration division

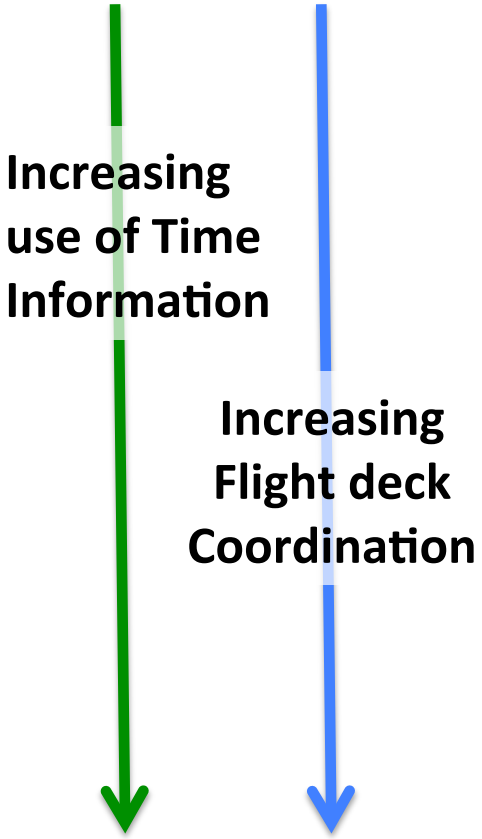
NASA Ames Research Center

OVERVIEW

- Airport Surface Operations: Taxi-out/Departures and **Surface Trajectory-Based Operations** (STBO: taxi with time requirements)
- Continuum of Surface Operations:
  Manual → Automated → Autonomy
- Current-day; near-term and far-term STBO
- Research on Pilot/Flight deck STBO
- 4DT STBO: A candidate for autonomous operations
  - Research Issues

OVERVIEW
Surface Trajectory-Based Operations (STBO)

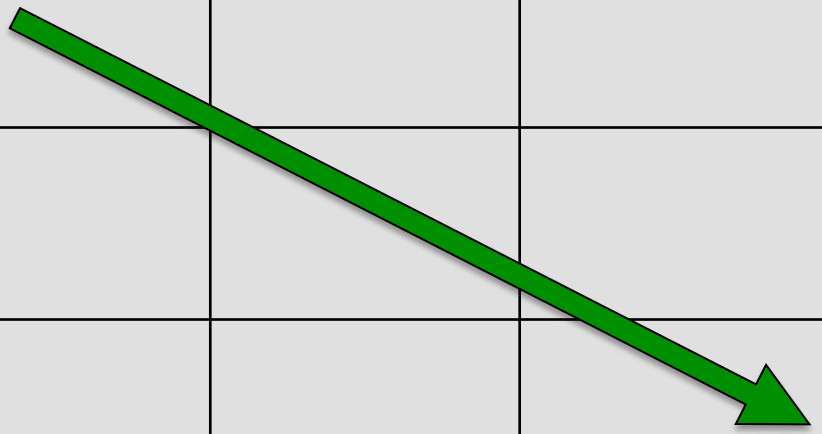
STBO = Adding time component to Surface Operations (taxi/departure)



- Current Day Surface Operations
- Current Day (EDCT – APREQ/CFR)
- Near-term (e.g., FAA STBO/NASA ATD2)
  - without flight deck component
- Future 4DT Surface Trajectory-based Operations (STBO) Vision (NASA/DLR)
  - with flight deck component

Continuum of Surface Operations Technologies
Manual → Increased Automation → Autonomy

		ATC / Surface Traffic Manager (STM)		
		Manual (Voice)	Manual (Voice) w/ Decision Aids	Autonomous STM
Pilot(s) / Flight Deck	Manual A/C Control			
	Manual A/C Control w/ Display Aids			
	Autonomous A/C Operations			



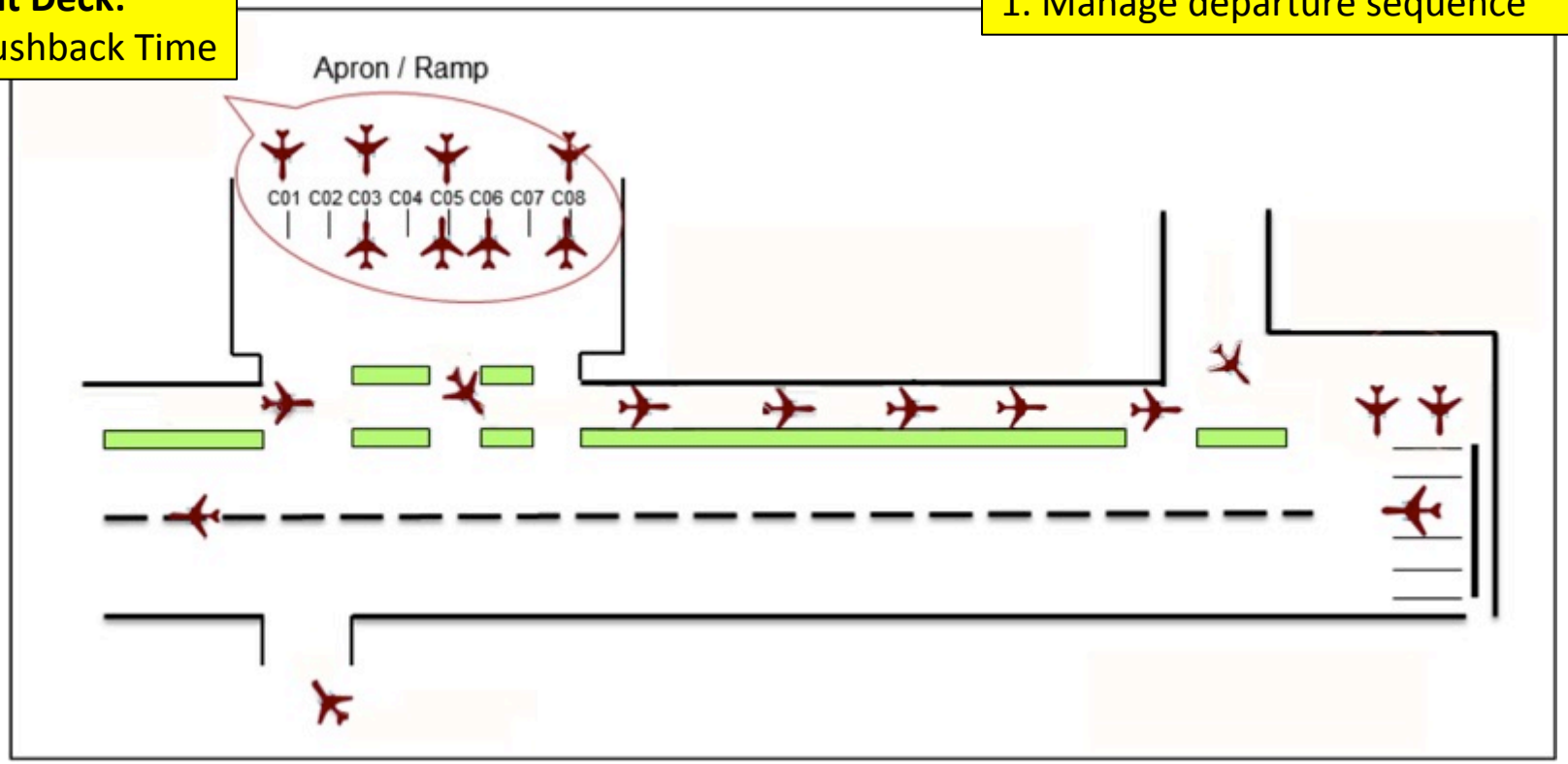
Continuum of Surface Operations Technologies
Manual → Increased Automation → Autonomy

		ATC / Surface Traffic Manager (STM)		
		Manual (Voice)	Manual (Voice) w/ Decision Aids	Autonomous STM
Pilot(s) / Flight Deck	Manual A/C Control	Current Day		
	Manual A/C Control w/ Display Aids			
	Autonomous A/C Operations			

Current Day Surface Operations

Flight Deck:
1. Pushback Time

ATC:
1. Manage departure sequence

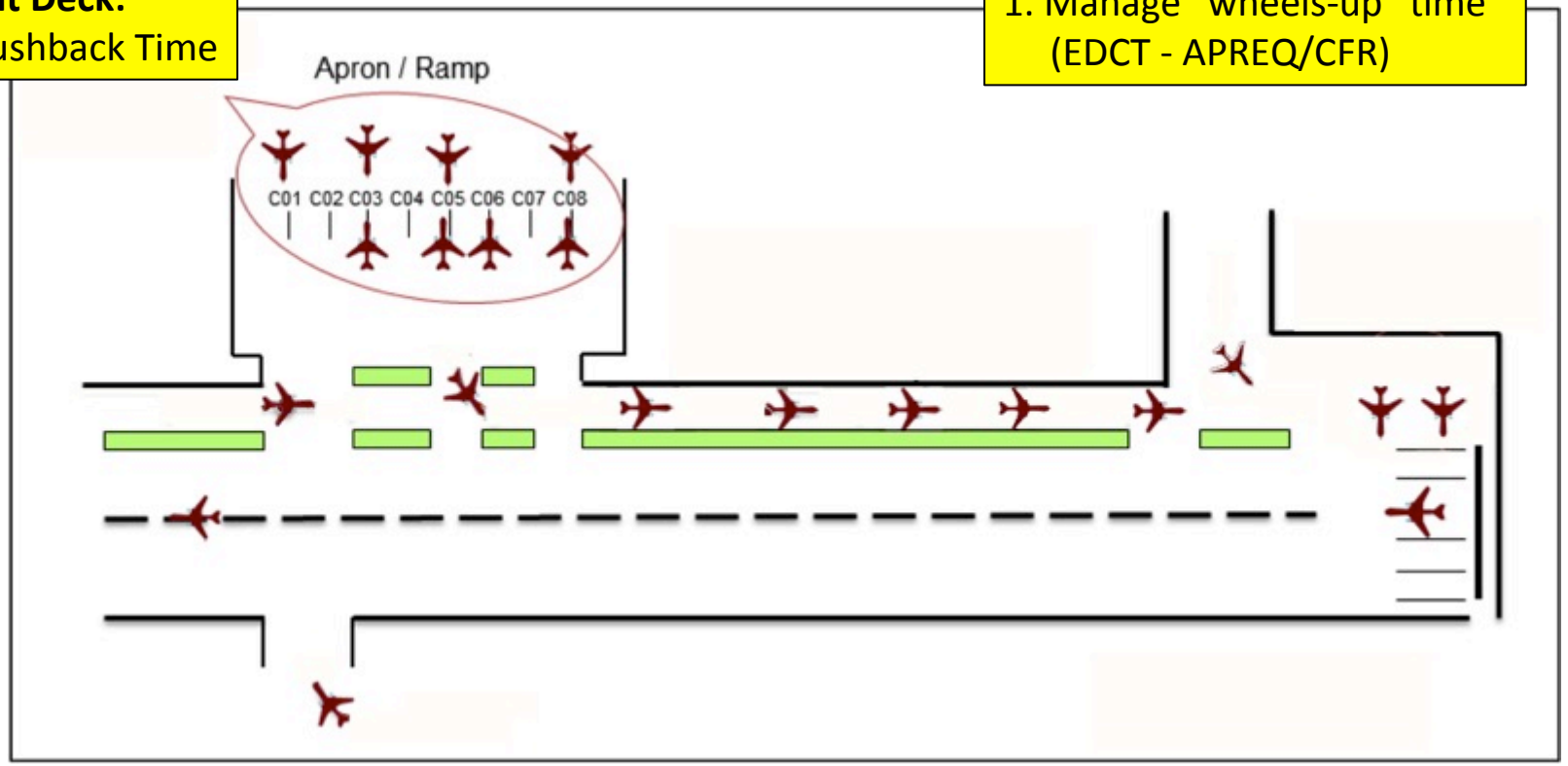


- Pilots manage pushback time to meet:
  - Scheduled departure/take-off time

Current Day (EDCT – APREQ/CFR)

Flight Deck:
1. Pushback Time

ATC:
1. Manage "wheels-up" time (EDCT - APREQ/CFR)



- Flight deck/pilots manage pushback time to meet:
  - "Wheels-up time"
- Flight deck/pilots have no information about:
  - Expected taxi time
  - Surface congestion
  - Departure queue size

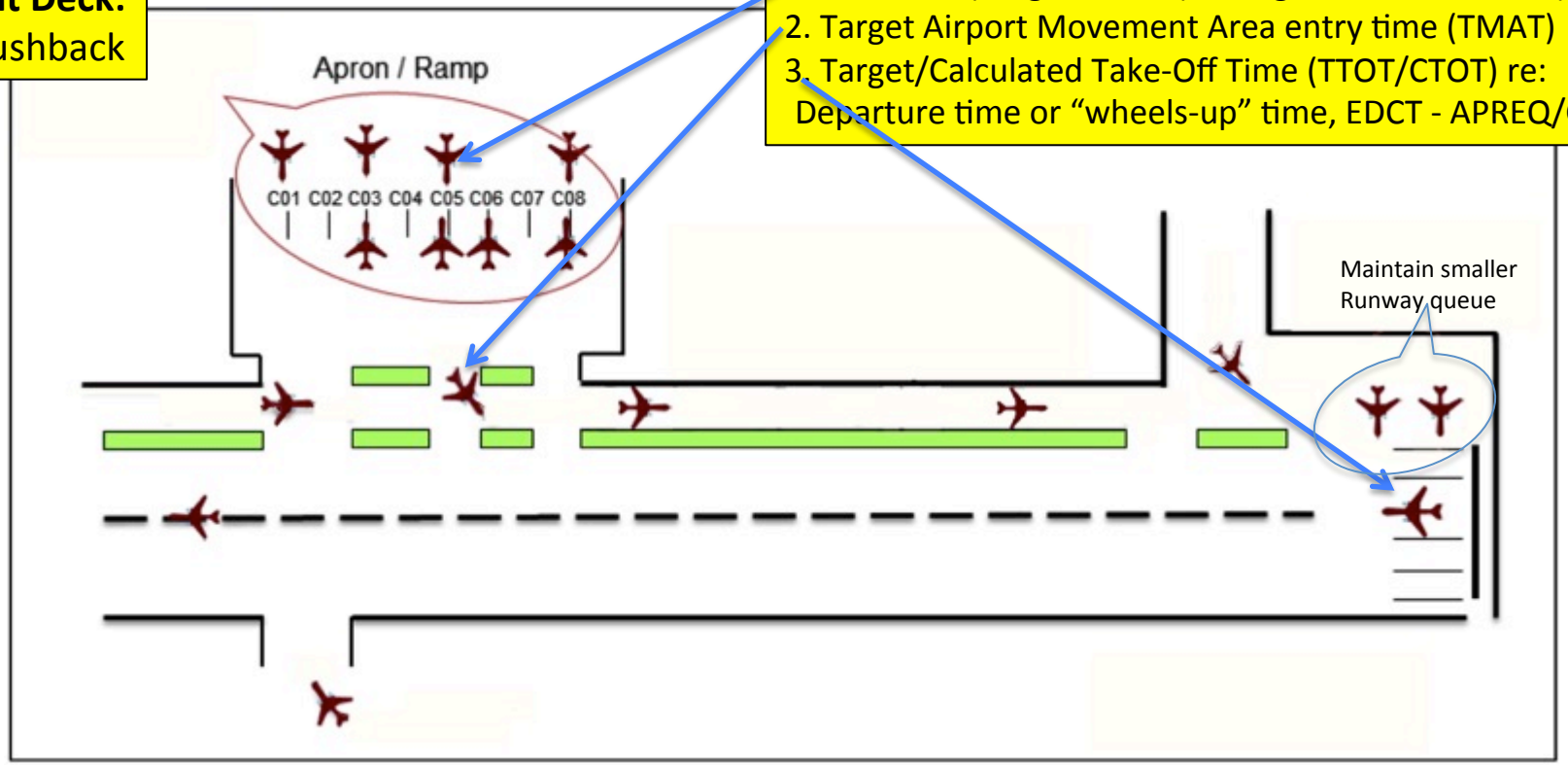
Continuum of Surface Operations Technologies
Manual → Increased Automation → Autonomy

		ATC / Surface Traffic Manager (STM)		
		Manual (Voice)	Manual (Voice) w/ Decision Aids	Autonomous STM
Pilot(s) / Flight Deck	Manual A/C Control		FAA STBO / NASA ATD2	
	Manual A/C Control w/ Display Aids			
	Autonomous A/C Operations			

Near-term (e.g., FAA STBO/NASA ATD2)
- without flight deck component

Flight Deck:
1. Pushback

ATC/Ramp manages
(with Decision Support Tools, DSTs):
1. Pushback (re: gate holds) – Target Off-Block Time (TOBT)
2. Target Airport Movement Area entry time (TMAT)
3. Target/Calculated Take-Off Time (TTOT/CTOT) re: Departure time or "wheels-up" time, EDCT - APREQ/CFR)



- Pilots manage pushback time to meet:
  - "Wheels-up time" (at KCLT, about 10% of flights)
- Pilots have no information about:
  - Expected taxi time
  - Surface congestion
  - Departure queue size

Continuum of Surface Operations Technologies
Manual → Increased Automation → Autonomy

		ATC / Surface Traffic Manager (STM)		
		Manual (Voice)	**Manual (Voice) w/ Decision Aids**	**Autonomous STM**
Pilot(s) / Flight Deck	**Manual A/C Control**			
	Manual A/C Control w/ Display Aids		NASA Flight Deck / SARDA STM	NASA Flight Deck / DLR STM
	Autonomous A/C Operations			

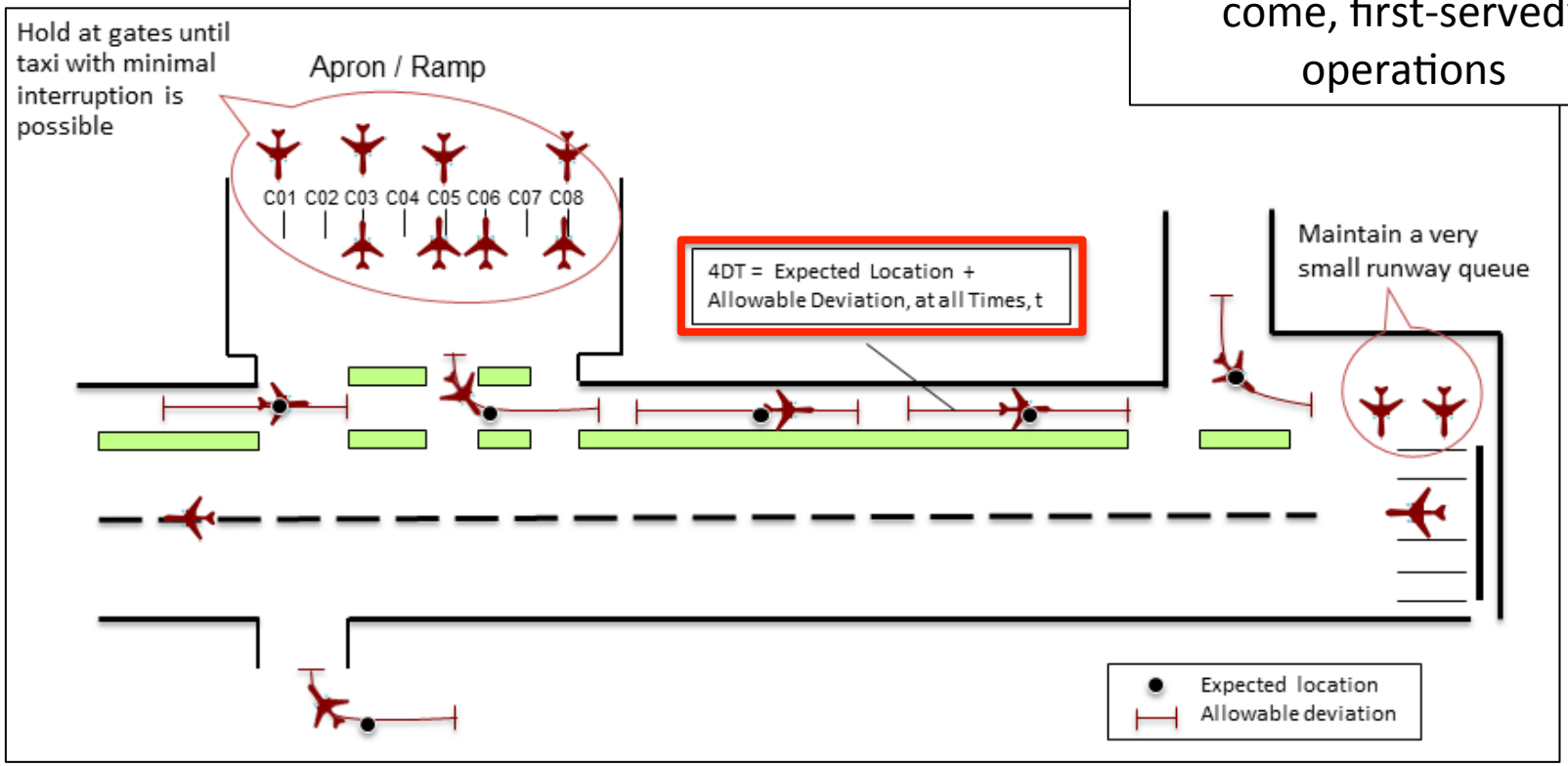
- Controller: Manual/voice ops, manual sequencing/ scheduling aids, manual deconfliction
- Pilot: Controls manually, info/displays for 4DT STBO

- Controller: Auto-routing, auto-deconfliction, auto-sequencing/scheduling, position timing
- Pilot: Controls manually, info/displays for 4DT STBO

Future 4DT Surface Trajectory-based Operations (STBO) Vision (NASA/DLR) - with flight deck component

Okuniak, Gerdes, Jakobi, Ludwig, Hooey, Foyle, Jung, & Zhu, AIAA/ATIO 2016 Conference, DLR/NASA Concept of Operations for Trajectory-based Taxi Operations

Transition from "first-come, first-served" operations

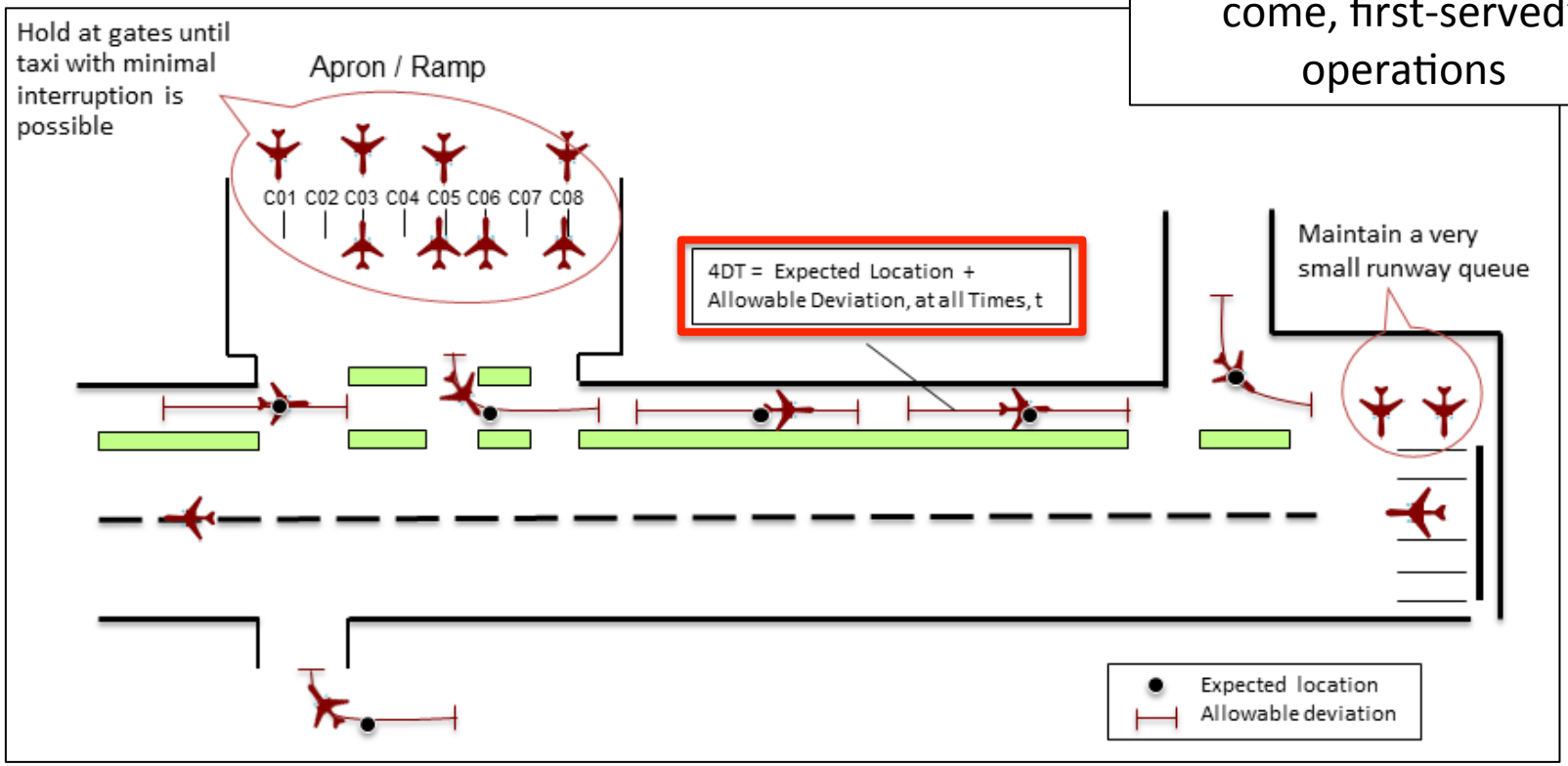


- Requirement to be at locations at specific time; defined (x_t, y_t) with certain tolerance
- DLR TRACC Surface Management System dynamically creates conflict-free routes
- Coordination between Flight Deck – ATC/Ramp re: location and times

Future 4DT Surface Trajectory-based Operations (STBO) Vision (NASA/DLR) - with flight deck component

Okuniak, Gerdes, Jakobi, Ludwig, Hooey, Foyle, Jung, & Zhu, AIAA/ATIO 2016 Conference, DLR/NASA Concept of Operations for Trajectory-based Taxi Operations

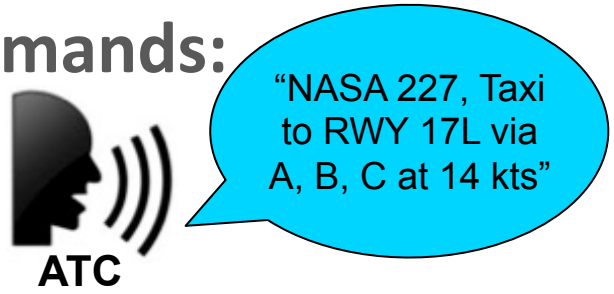
Transition from "first-come, first-served" operations



- Enables dynamic surface flow re-planning
- Enables increasingly precise taxi routing plans for improved surface traffic flow efficiency
- Flight deck component allows for coordination with ATC re: schedule issues (e.g., maintenance, FMS, weights/balances, RWY changes, etc.)
- Extension of FAA/NASA STBO concept
- Would enable aircraft traffic to continue rolling through Active RWY Crossings, instead of stopping aircraft and requiring ATC to do "batch" crossings of arrivals
- Facilitate timed runway take-off window conformance (+/- 5 min EDCTs, -2/+1 min APREQ/CFRs)

4DT STBO: Taxi Clearances w/ Speed Commands: Taxi Time-based Conformance

Summary HITL sim data from: *Foyle, Hooey, Bakowski & Kunkle, Int'l Journal of Aviation Psychology, 2015*



Taxi Clearance	Required time of Arrival (RTA) Performance	Safety
• Non-specified acceleration/deceleration speed profile (n = 8 pilots)	**Not able to achieve accurate RTAs**	Slightly increased visual demand, as compared to baseline
• Specified acceleration/deceleration profile (1kt/sec) • Speed-conformance bound (+/- 1.5 kts) (n = 18 pilots)	**Good RTA performance**	**• Increased workload and visual demand** **• 14/18 pilots rated "unsafe"**

- Taxiing Captain cannot "tightly control/track" speed, navigate, and maintain separation.
- "Open-loop" control compounds error

ConOps Implications:

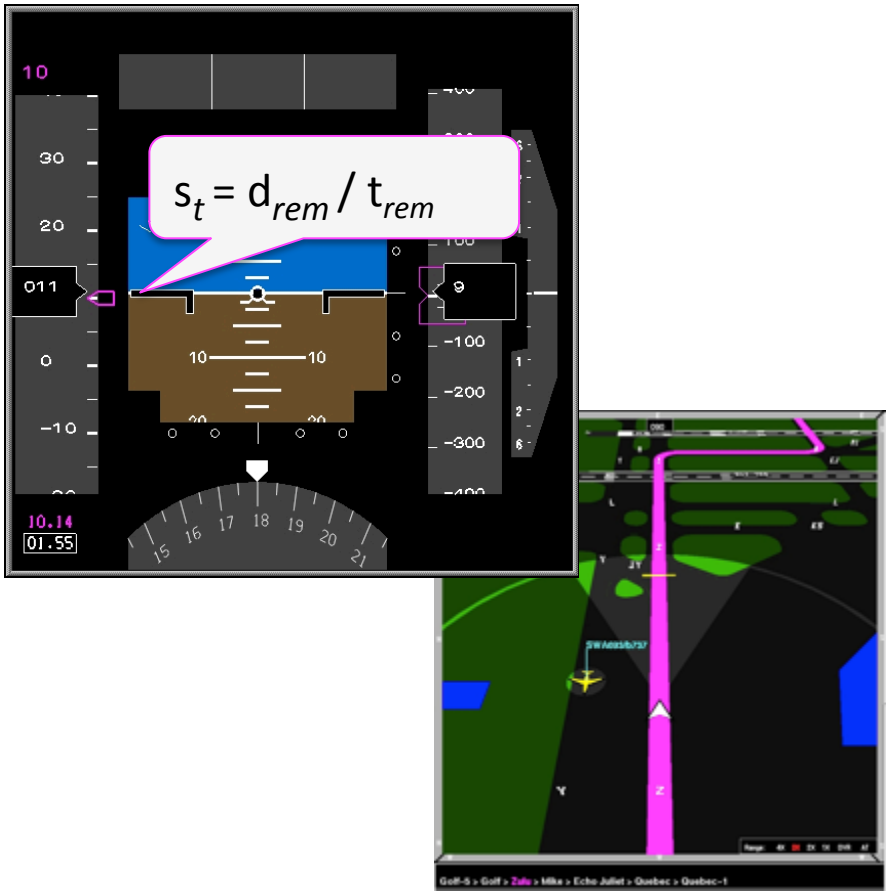
- Incorporating speed into the taxi clearance alone is not sufficient for the performance/safety balance
- There is a **requirement for human-centered flight deck display algorithms**

4DT STBO: Flight Deck Display Design

"3.5-DT" / 4DT Speed-based Flight Deck Display

Foyle, Hooey, Bakowski & Kunkle, Int'l Journal of Aviation Psychology, 2015

- **"Closed-loop" speed control** to specific airport locations



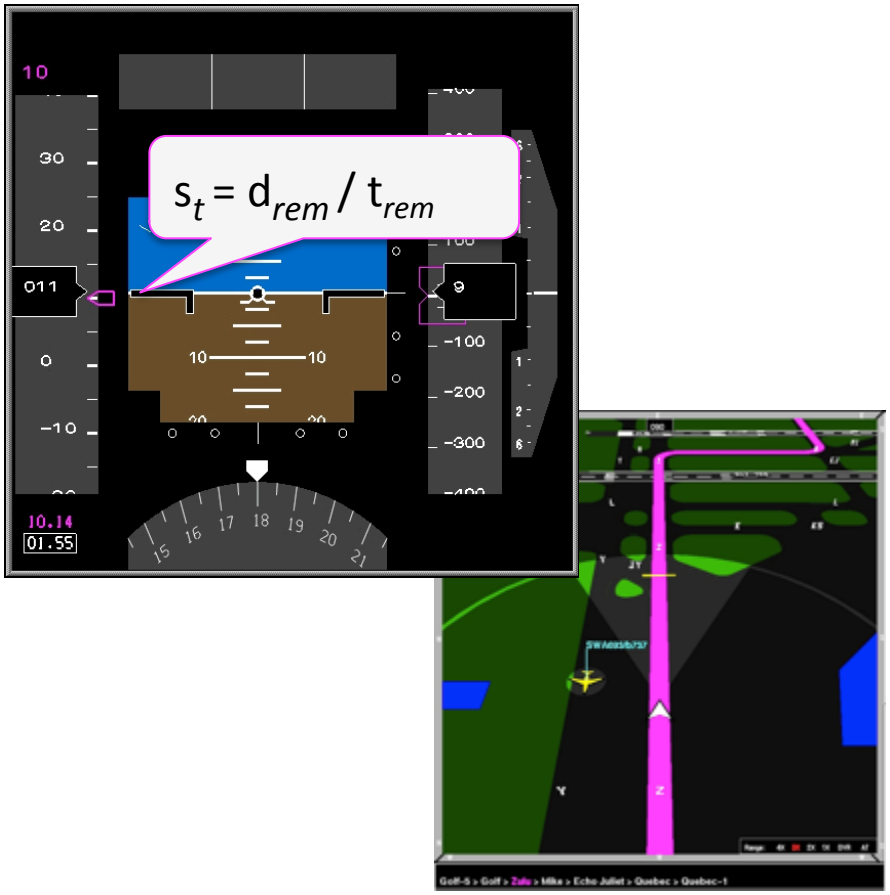
Taxi Clearance	Required time of Arrival (RTA) Performance	Safety
• Non-specified acceleration/ deceleration speed profile (n = 8 pilots)	**Not able to achieve accurate RTAs**	Slightly increased visual demand, as compared to baseline
• Specified acceleration/ deceleration profile (1kt/sec) • Speed-conformance bound (+/- 1.5 kts) (n = 18 pilots)	**Good RTA performance**	• **Increased workload and visual demand** • **14/18 pilots rated "unsafe"**
• "3.5-DT" Speed Display (n = 8 pilots)	**Good RTA performance**	**Low visual demand**

4DT STBO: Flight Deck Display Design/Philosophy

"3.5-DT" / 4DT Speed-based Flight Deck Display

Foyle, Hooey, Bakowski & Kunkle, Int'l Journal of Aviation Psychology, 2015

- **"Closed-loop" speed control** to specific airport locations



Full 4DT Location-based Flight Deck Display

Bakowski, Hooey, Foyle, & Wolter, 2015, AHFE
Bakowski, Hooey, & Foyle, 2017, DASC

- **Status-at-a-glance** display to maximize 'eyes-out' time
- Enable **strategic use** – pilots do not need to track speed continuously (anywhere in pink band is 'in conformance')
- **Display expected position with tolerance** and allow pilots to use expertise to control aircraft (e.g., "human/pilot-centered")

Continuum of Surface Operations Technologies
Manual → Increased Automation → Autonomy

		ATC / Surface Traffic Manager (STM)		
		Manual (Voice)	Manual (Voice) w/ Decision Aids	Autonomous STM
Pilot(s) / Flight Deck	Manual A/C Control			
	Manual A/C Control w/ Display Aids			
	Autonomous A/C Operations	Future	Future	Future

Automation/Autonomy in 4DT Surface Trajectory-Based Operations (STBO)

TRACC: "Taxi Routes for Aircraft: Creation and Controlling" Surface Management System – Germany's DLR

- Creates conflict free routes/re-routes
- Non-Conformance within 50 m (164 ft) of deviation from expected x, y position
- Dynamic, multiple speed changes (up to 5) along taxi route

Autonomous Surface Operations:

- Enables 4DT STBO efficiencies
- Distributed architecture (Airport/Tower/Aircraft)
- Surface traffic manager
  - 4DT STBO operations (i.e., times at AMA entry, taxi merge points, rolling runway crossings, runway departure queue)
  - Routing/re-routing
  - Traffic de-confliction
- Candidate Auto-taxi propulsion
  - Wheel-bots
  - Electric tugs
  - Auto-taxi aircraft

Automation/Autonomy in 4DT Surface Trajectory-Based Operations (STBO)

TRACC: "Taxi Routes for Aircraft: Creation and Controlling" Surface Management System – Germany's DLR

- Creates conflict free routes/re-routes
- Non-Conformance within 50 m (164 ft) of deviation from expected x, y position
- Dynamic, multiple speed changes (up to 5) along taxi route

Autonomous Surface Operations:

Candidate initial architecture (NASA/DLR Concept):

- Ground/Tower: Surface Traffic Management
  - Issue STBO Clearances (Routes w/ times)
  - Re-routing for efficiency or non-conformance
  - Traffic deconfliction
- Aircraft:
  - Aircraft navigation
  - Aircraft movement (steering, speeds, turns)
  - Additional On-board Conflict Detection and Resolution (CD&R)

Function	ATC	Aircraft
Scheduling	**X**	
Routing	**X**	
Deconfliction	**X**	**X**
Execution		**X**

STBO with Autonomous flight deck component

Pilot(s) responsible for aircraft/crew & passenger safety

Enabling Pilots/Flight deck Situation Awareness

Need for “status-at-a-glance” awareness and intent displays

		ATC / Surface Traffic Manager		
		Manual	**Manual / Aided**	**Autonomous**
Pilot / Flight Deck	**Manual**	Current-day	FAA STBO / NASA ATD2	
	Manual / Aided		NASA / DLR	NASA / DLR
	Autonomous	Future	Future	Future

STBO with Autonomous flight deck component

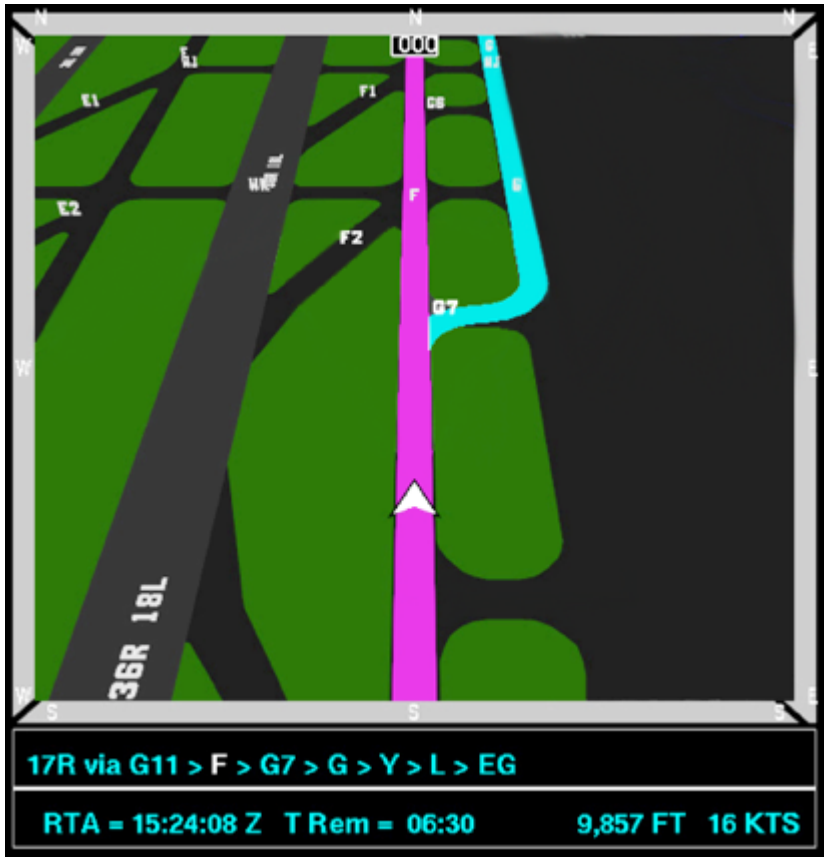
Pilot(s) responsible for aircraft/crew & passenger safety

Enabling Pilots/Flight deck Situation Awareness

Need for “status-at-a-glance” awareness and intent displays

Re-routing Pending

Bakowski, Foyle, Hooey, Meyer & Wolter, AHFE 2012



Current route with Other Traffic HOLD

Bakowski, Hooey, Foyle, Wolter & Cheng, DASC 2013

STBO with Autonomous flight deck component

Pilot(s) responsible for aircraft/crew & passenger safety

Enabling Pilots/Flight deck Situation Awareness and Flight Deck workflow/procedure integration

Research issues, re: Pilot roles:

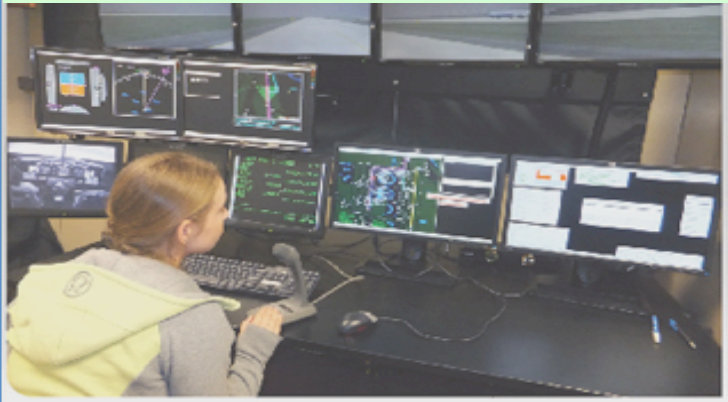
- Taxi clearance (how to load? pilot approve if auto-load?)
- 4DT STBO – speed/time updates (approve? Auto-load?)
- Departing Runway (changes, FMS, weights, temps, etc)
- Runway crossings, "wheels-up" times
- Braking – hot brakes (take-off abort)
  - Airports are not flat; KCLT, DFW varies 50ft
  - 747-8 *1 Million lbs* fully loaded
- Monitoring: - Traffic (aircraft, pedestrian, vehicle) – Separation assurance
  - Ownship aircraft intent (stopping, turning, waiting to cross active runway)
- (Non) Conformance: - Mid-taxi stopping / abort – FMS, passengers, weights
  - For 4DT STBO – interactions re: dynamic STM system; # updates
- Pilot Intervention? Revert to manual or abort taxi, or unable to make time b/c of flight deck, equipment, passenger, baggage, etc. issues

NASA Ames Research Center

NASA/DLR MOA Collaboration
NASA Ames Research Center
8/22/17 – 8/24/17

Flight Deck Surface Trajectory-Based Operations

David C. Foyle, Becky L. Hooey, NASA Ames Research Center
Deborah L. Bakowski, San Jose State University / NASA Ames



POCs:
David.Foyle@nasa.gov
Becky.L.Hooey@nasa.gov
Debi.Bakowski@nasa.gov

Human Systems integration division

URL: http://humansystems.arc.nasa.gov/groups/HCSL

Additional Slides

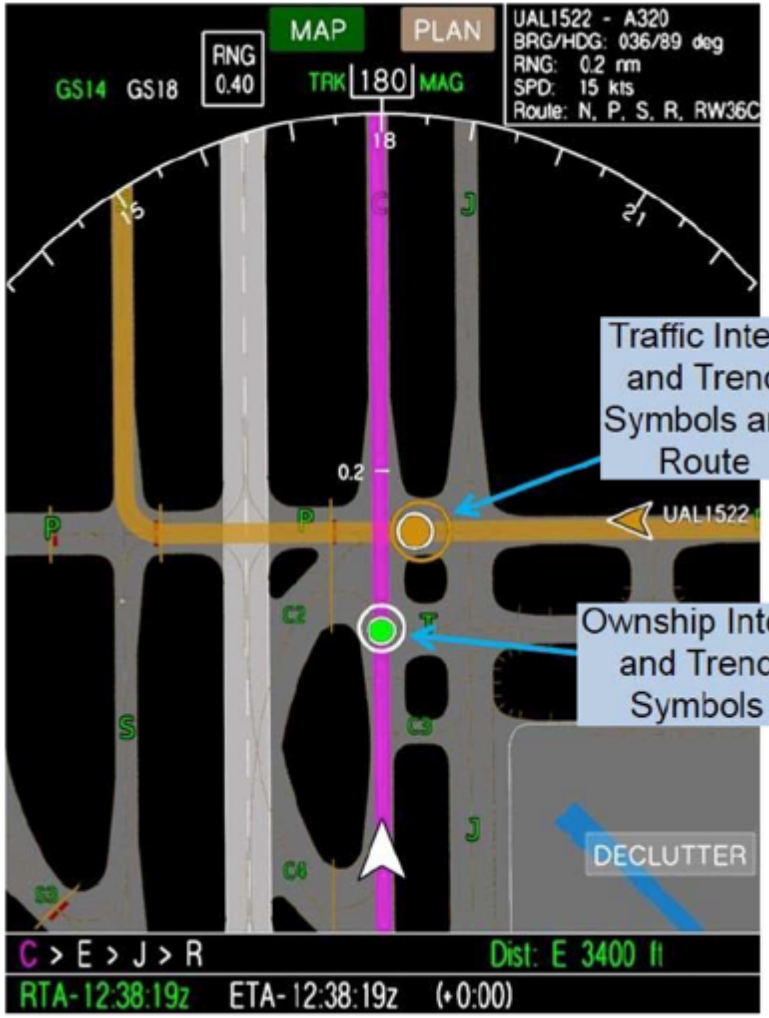
4DT Flight-Deck Display

Cleared-to-Taxi Route

Ownship

4DT with allowable deviation

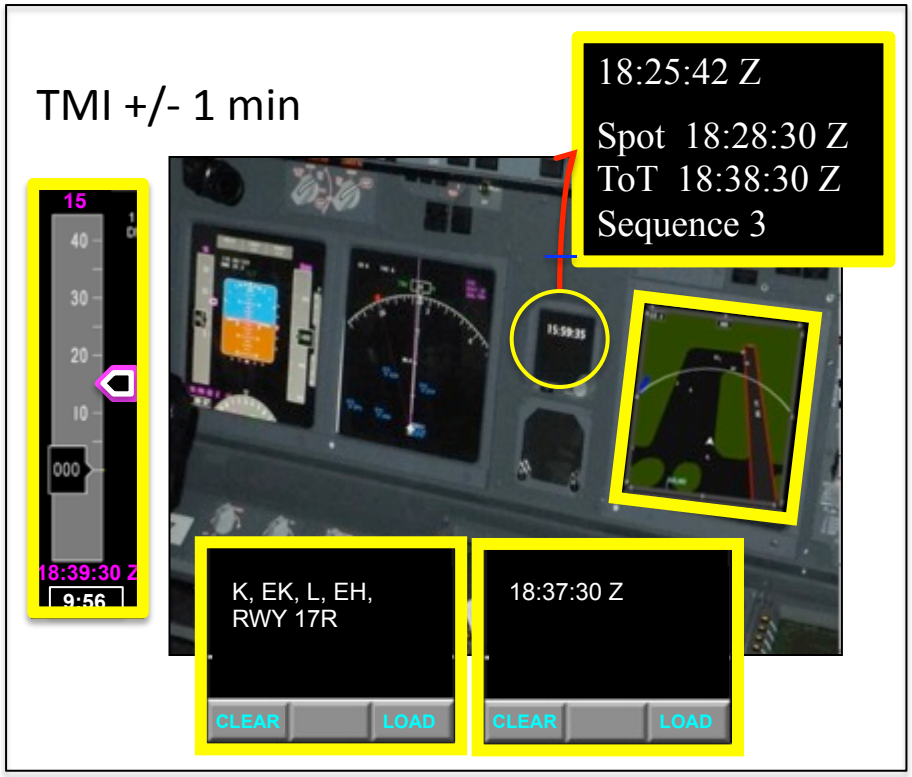
Taxi Route



Jones et al NASA TP 2016-219172

STBO with flight deck component and Information Sharing Displays

Enables better flight deck workflow prior to departure



"For NextGen time-based operations, how useful were the following pieces of information in supporting time-based taxi (your ability to meet your takeoff time?)"

Information Source	Response frequency (n=10) of usefulness ratings: Not at all 1	2	Borderline 3	4	Very much 5
Assigned Pushback time	-	-	1	4	5
Spot-release time	1	-	1	5	3
Takeoff Time	-	-	-	7	3
Departure Sequence	-	2	-	2	6
Speed Advisory on PFD	-	1	4	2	3
Time Remaining to Takeoff Time	-	-	4	4	2

ATC-Pilot HITL Sim: *Foyle, Bakowski, Hooey, Cheng & Wolter, HCI-Aero, 2014)*

NASA Ames Research Center

HUMAN CENTERED SYSTEMS LAB

Airport and Terminal Area Simulator (ATAS)

David Foyle, PhD, NASA
Becky Hooey, PhD, NASA
Debi Bakowski, MS SJSU
Glenn Meyer, MA Dell
Capt. Rob Koteskey, MA

POCs:
David.Foyle@nasa.gov
650-604-3053
Becky.L.Hooey@nasa.gov
650-604-2399

Human Systems integration division

URL: http://humansystems.arc.nasa.gov/groups/HCSL

Flight Deck Pilot-in-the-Loop 4DT Studies
Human-Centered Systems Lab (HCSL)

Proof-of-Concept Study (2014)

- Proof-of-concept simulation.
- Demonstrated the feasibility of the 4DT concept, from the pilot's perspective.

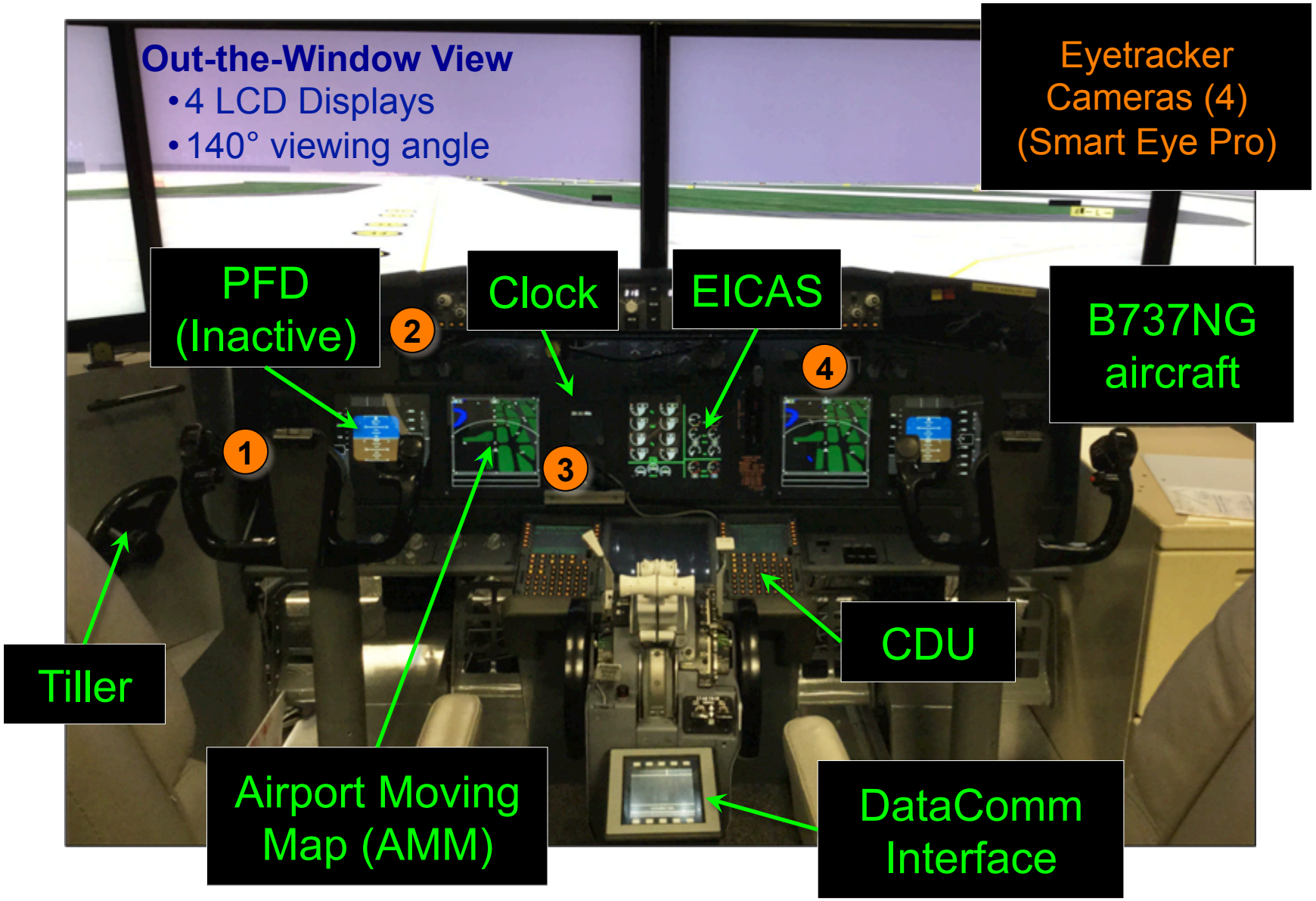
Bakowski, Hooey, Foyle, & Wolter
Applied Human Factors and Ergonomics (AHFE 2015)

4DT Display Comparison Study (2016)

- Compared 4DT display formats.
- More robust operating conditions than 2014 study.
  - 4DT speed updates
  - Range of taxi speeds
- Several parameters based on the TRACC system.

Bakowski, Hooey, & Foyle
Digital Avionics Systems Conference (DASC 2017)

Airport and Terminal Area Simulator (ATAS)
Human-Centered Systems Lab (HCSL)

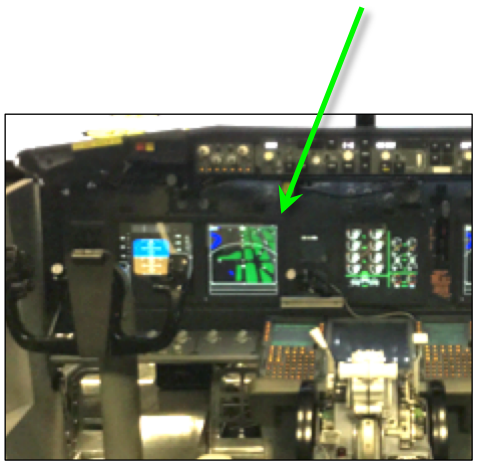


Flight Deck 4DT Proof-of-Concept Study (2014)

Airport Moving Map (AMM)

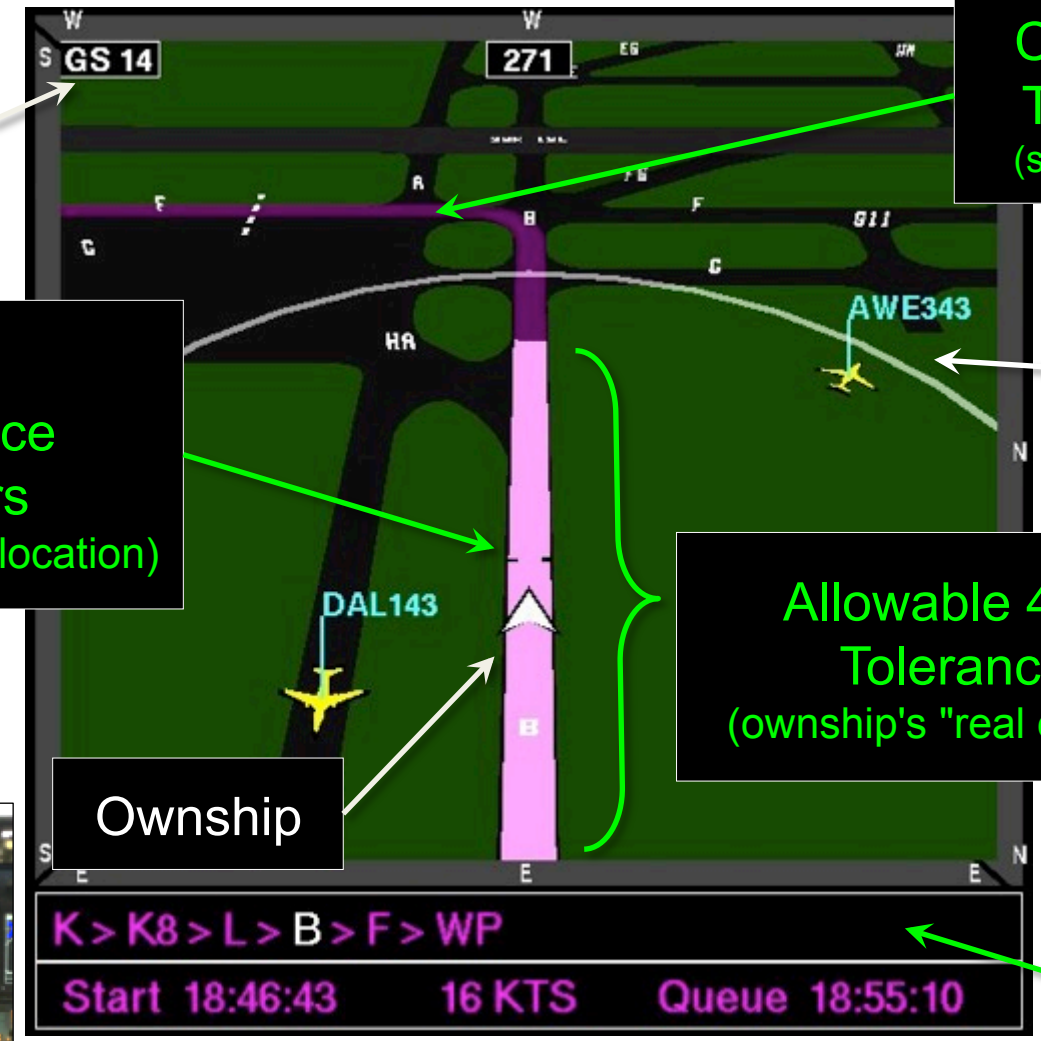
Ownship's Ground Speed

Traffic displayed within de-clutter circle



Flight Deck 4DT Proof-of-Concept Study (2014)

Airport Moving Map (AMM) *Augmented with 4DT Clearance Information*



Ownship's Ground Speed

Cleared-to-Taxi Route
(spot to runway)

Traffic displayed within de-clutter circle

4DT Reference Markers
(expected 4DT location)

Allowable 4DT Tolerance
(ownship's "real estate")

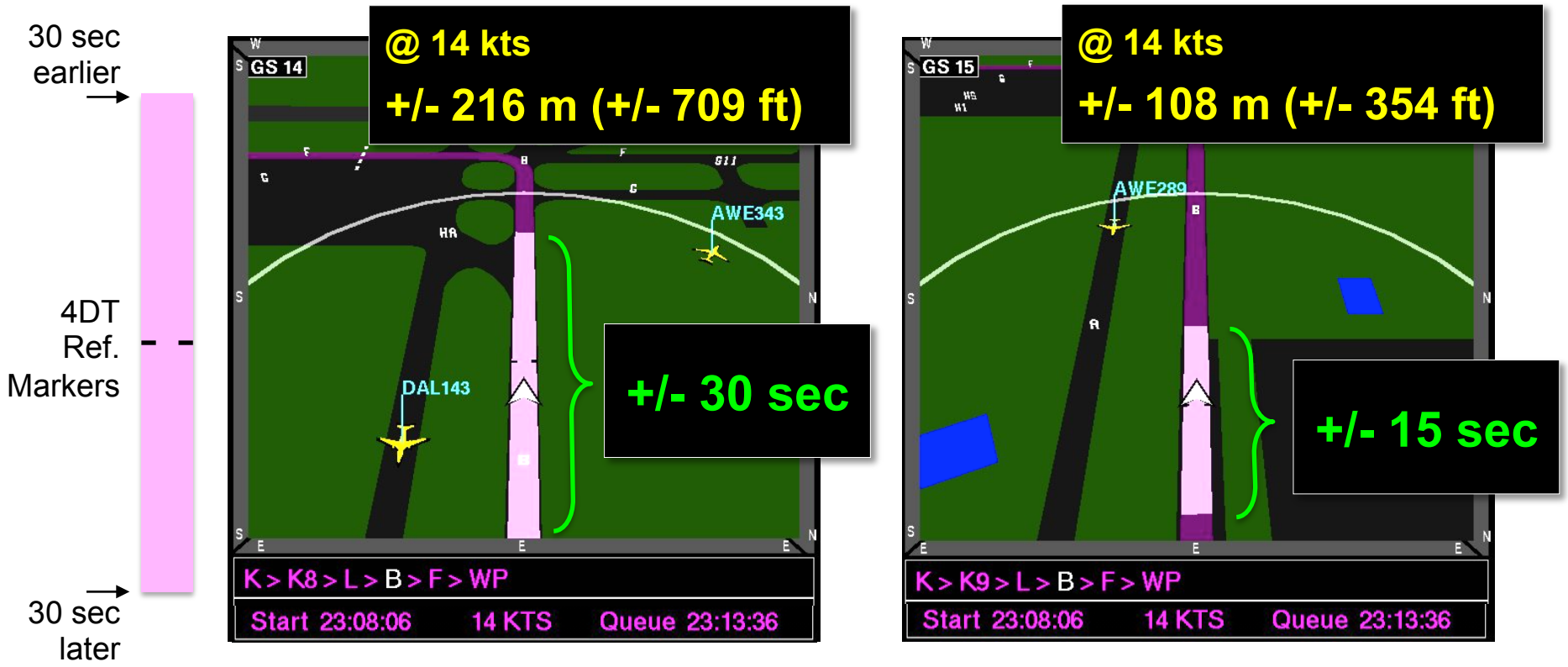
Ownship

4DT Clearance Text

Flight Deck 4DT Proof-of-Concept Study (2014)

	ATC Schedule Information	Required Speed	Allowable Deviation	Flight Deck Display
Condition 1 **Current-Day Flight Deck Equipage**	Pushback Begin Taxi	Not Specified	Not Specified	
Condition 2 **Speed Advisory**	Pushback Begin Taxi	ATC-issued Speed	Not Specified	
Condition 3 **4DT +/- 15 sec**	4DT Speed Profile	4DT Speed Profile	+/- 15 sec	
Condition 4 **4DT +/- 30 sec**	4DT Speed Profile	4DT Speed Profile	+/- 30 sec	

Flight Deck 4DT Proof-of-Concept Study (2014)

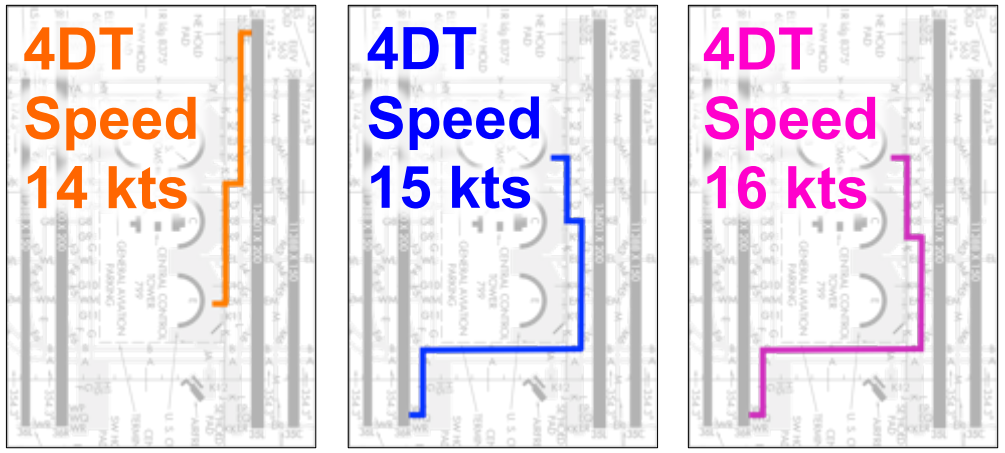


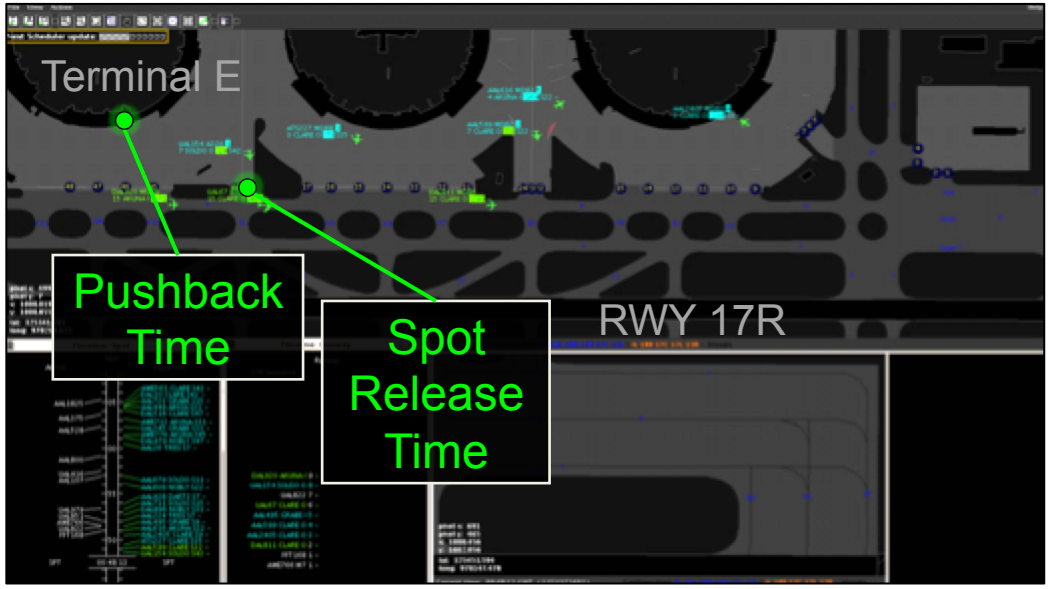
Time-based allowable tolerance band (speed × time = distance)

14 kts	×	**+/- 30 sec**	=	**+/- 216 m**
4DT Straightaway Speed (kts --> ft per sec)		Allowable *Time* Deviation		Distance (Length) of Allowable 4DT Tolerance Band

Flight Deck 4DT Proof-of-Concept Study (2014)

- Dallas/Fort Worth Airport (DFW)
- 13 Captains
- Experimenter First Officer
  - assisted with navigation, DataComm
- 12 experimental trials
  - 4 experimental conditions
  - 3 speed/route combinations
  - practice trials before each block
  - 2 4DT conditions always last
- Spot and Runway Departure Advisor (SARDA):
  - surface management system
  - ran in closed-loop mode
  - triggered Pushback and Taxi
  - queue-entry derived from ToT
  - SARDA traffic appeared OTW





Flight Deck 4DT Proof-of-Concept Study (2014)

4DT End

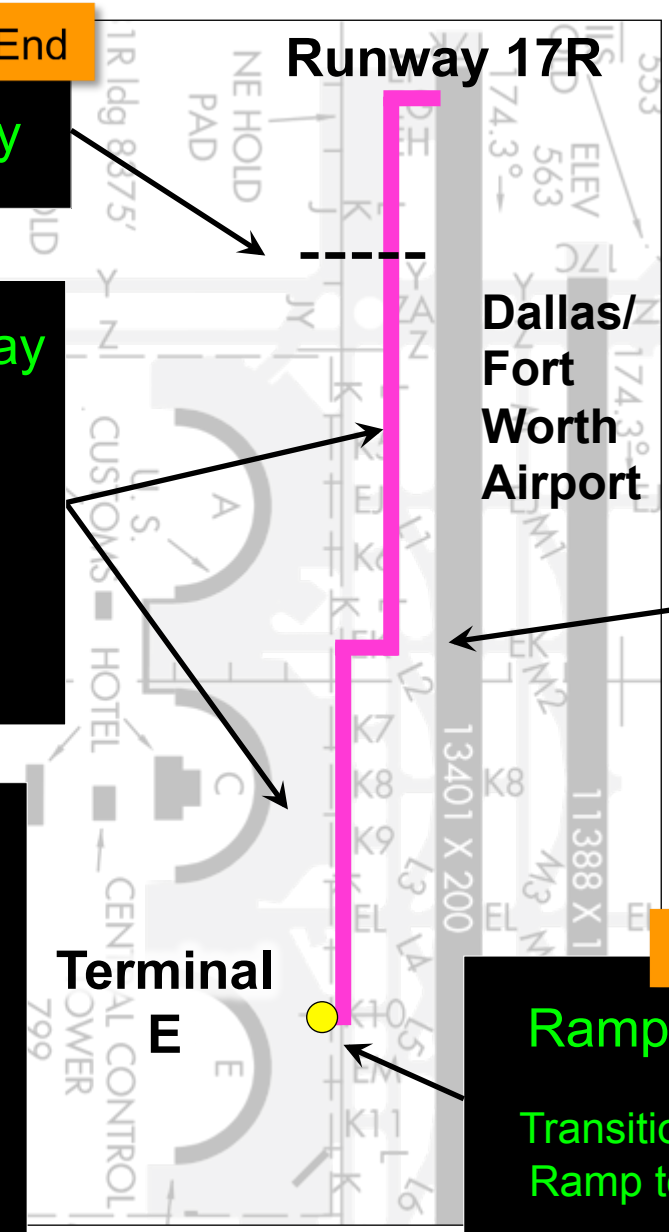
Queue-Entry

4DT Straightaway Speed was held constant in each trial

e.g., 14 kts

4DT Acceleration /Deceleration Rate
1 kt per sec

Beginning of 4DT Taxi Entering/Exiting Turns



4DT Start

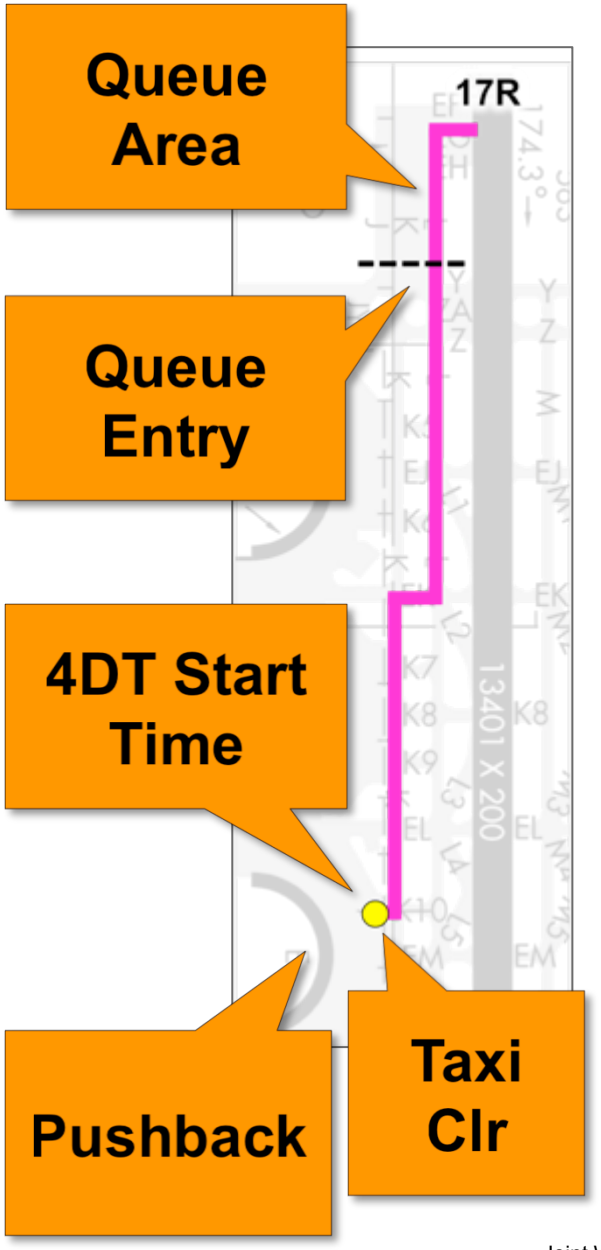
Ramp Spot

Transition from Ramp to AMA

4DT Turn Speed
10 kts

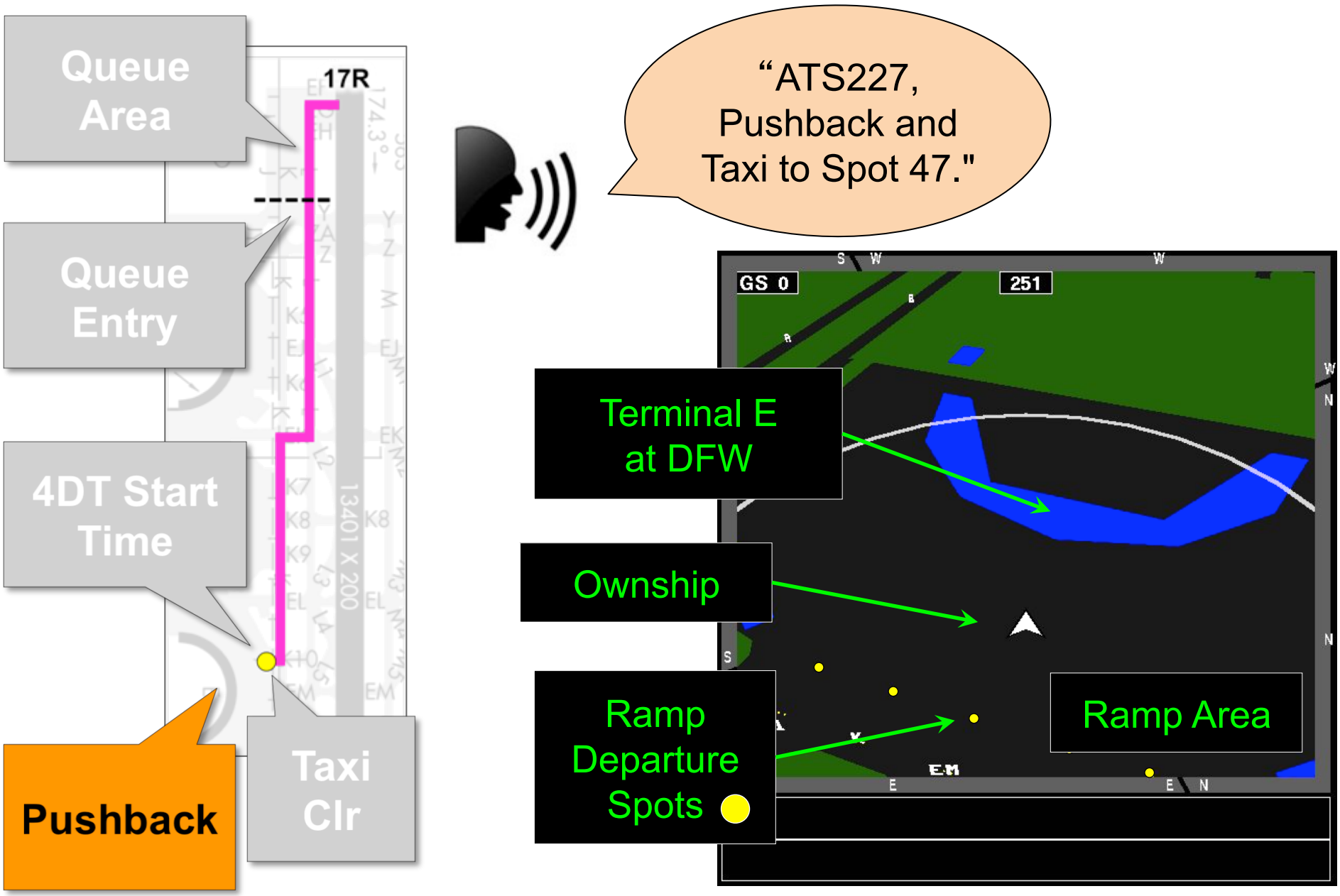
**Time*-based tolerance band

Flight Deck 4DT Proof-of-Concept Study (2014)

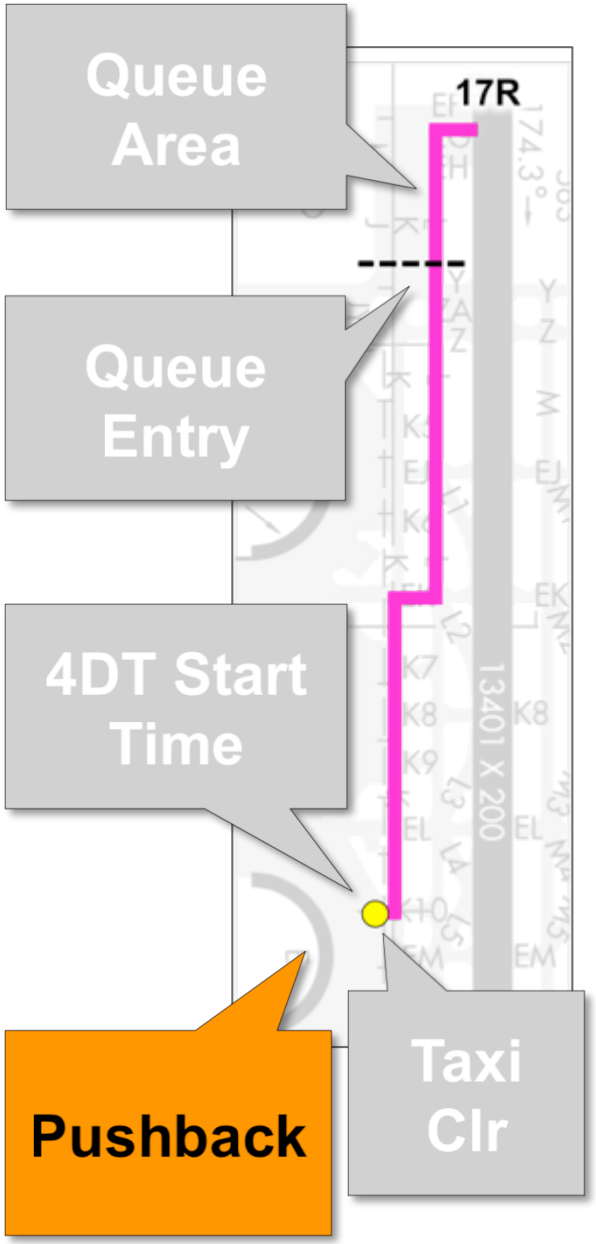


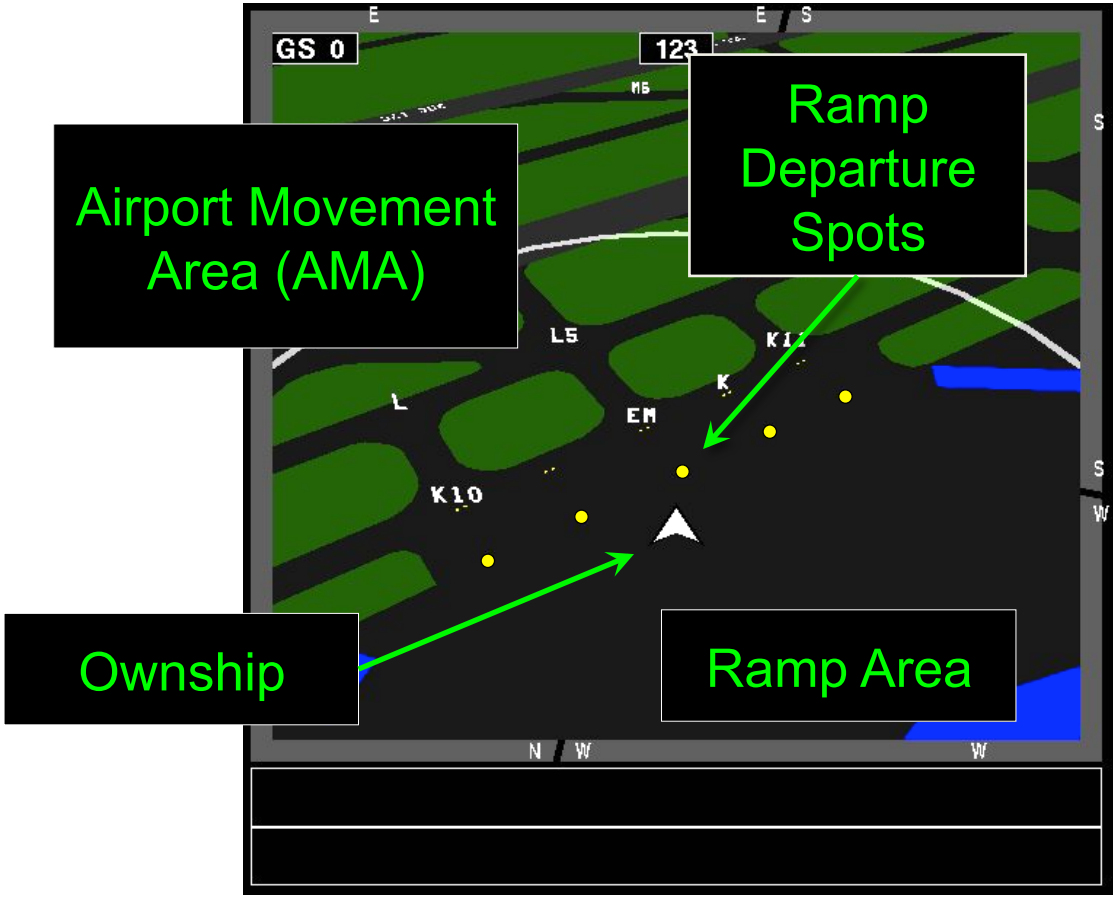
Example Trial

Flight Deck 4DT Proof-of-Concept Study (2014)

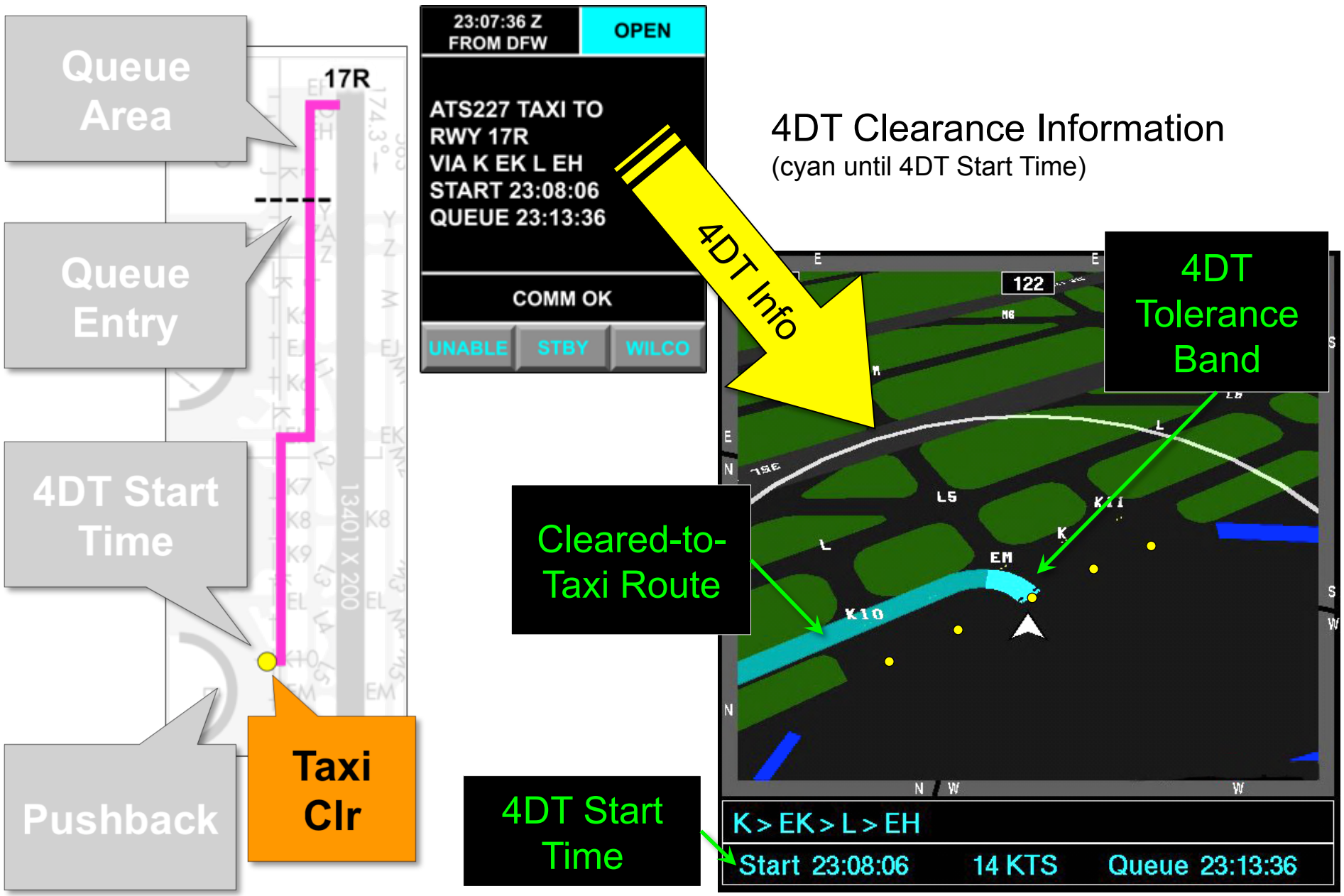


Flight Deck 4DT Proof-of-Concept Study (2014)

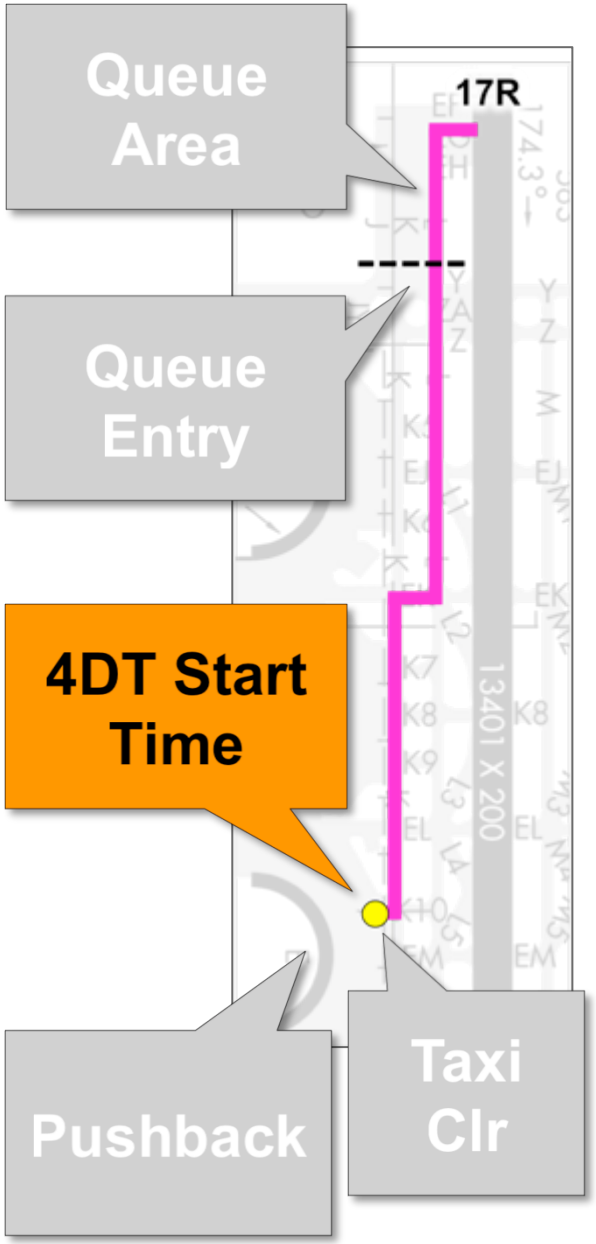




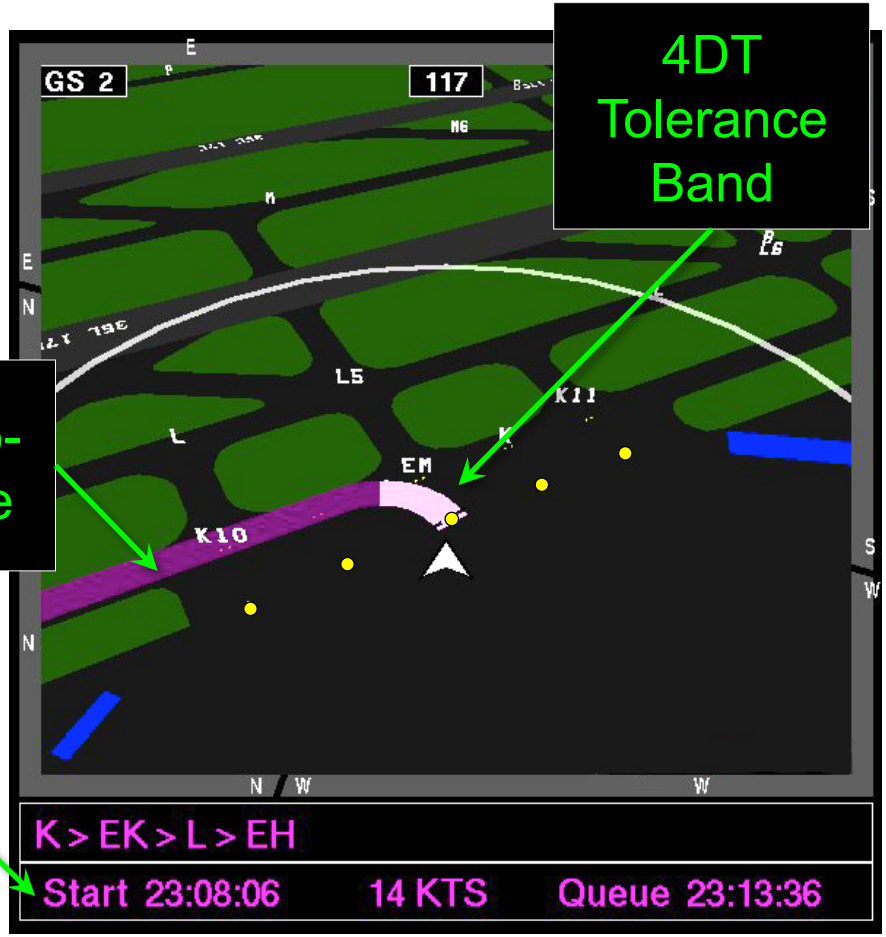
Flight Deck 4DT Proof-of-Concept Study (2014)



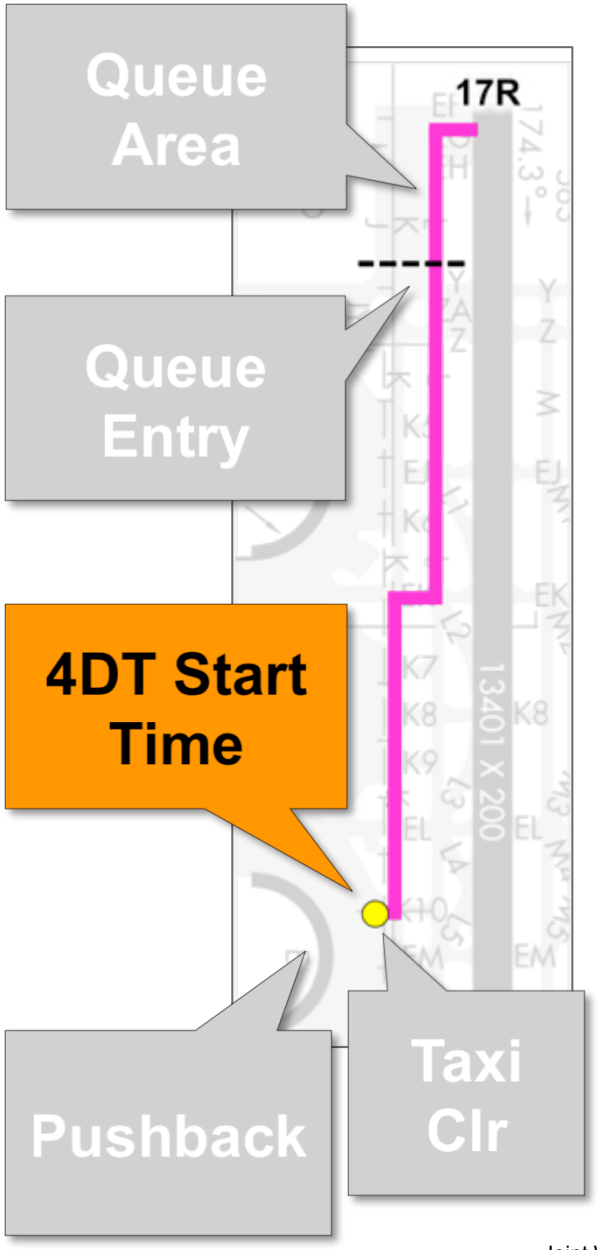
Flight Deck 4DT Proof-of-Concept Study (2014)



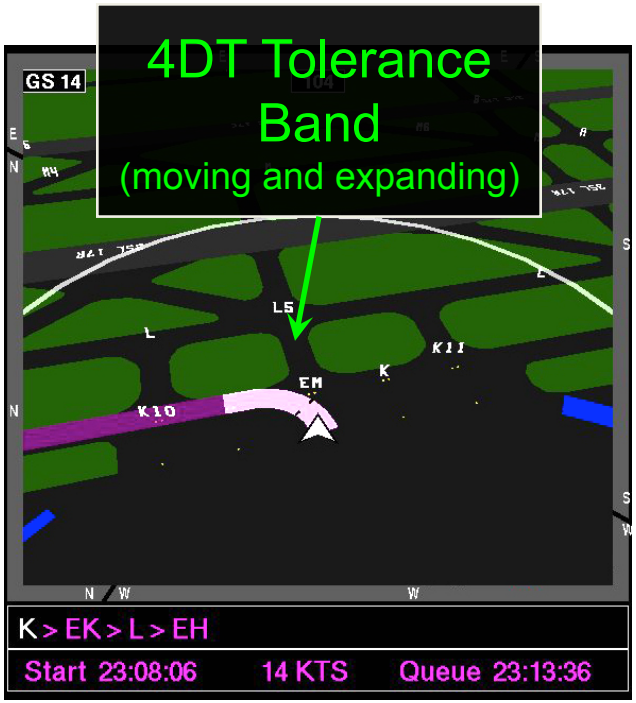
- 4DT Start Time: 30 sec after Taxi Clearance.
- Defined by the 4DT speed profile.
- Auditory Chime and 4DT information turns magenta.
- Pilot enters the AMA and begins to taxi.

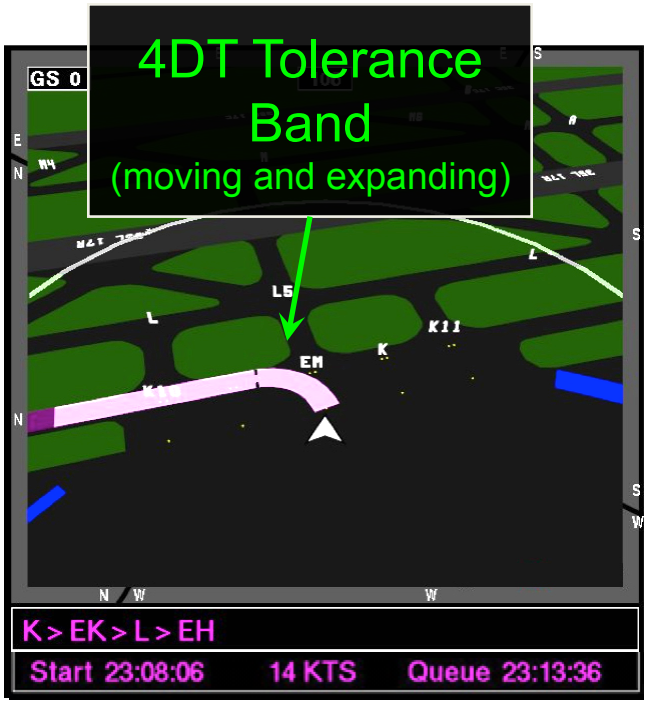


Flight Deck 4DT Proof-of-Concept Study (2014)

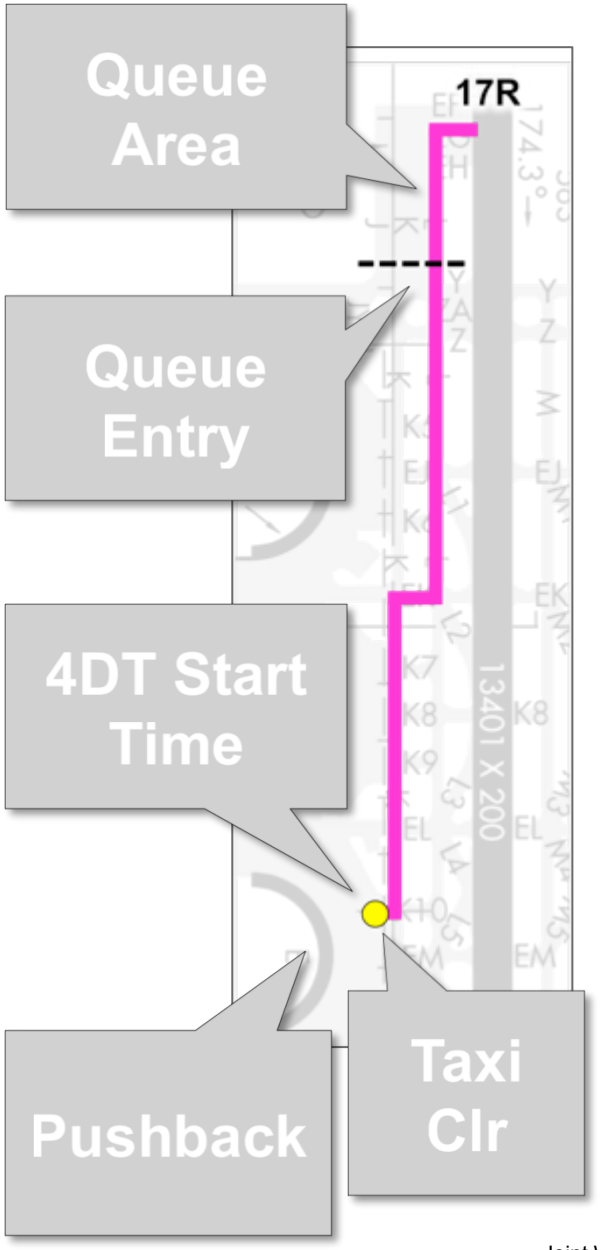


- 4DT Tolerance Band accelerates from 0 kts to 14 kts at 1 kt per sec.
- Pilot Instructions:
  - In compliance with the 4DT clearance when the ownship icon is within the tolerance band.
  - No need to track the 4DT reference markers precisely.

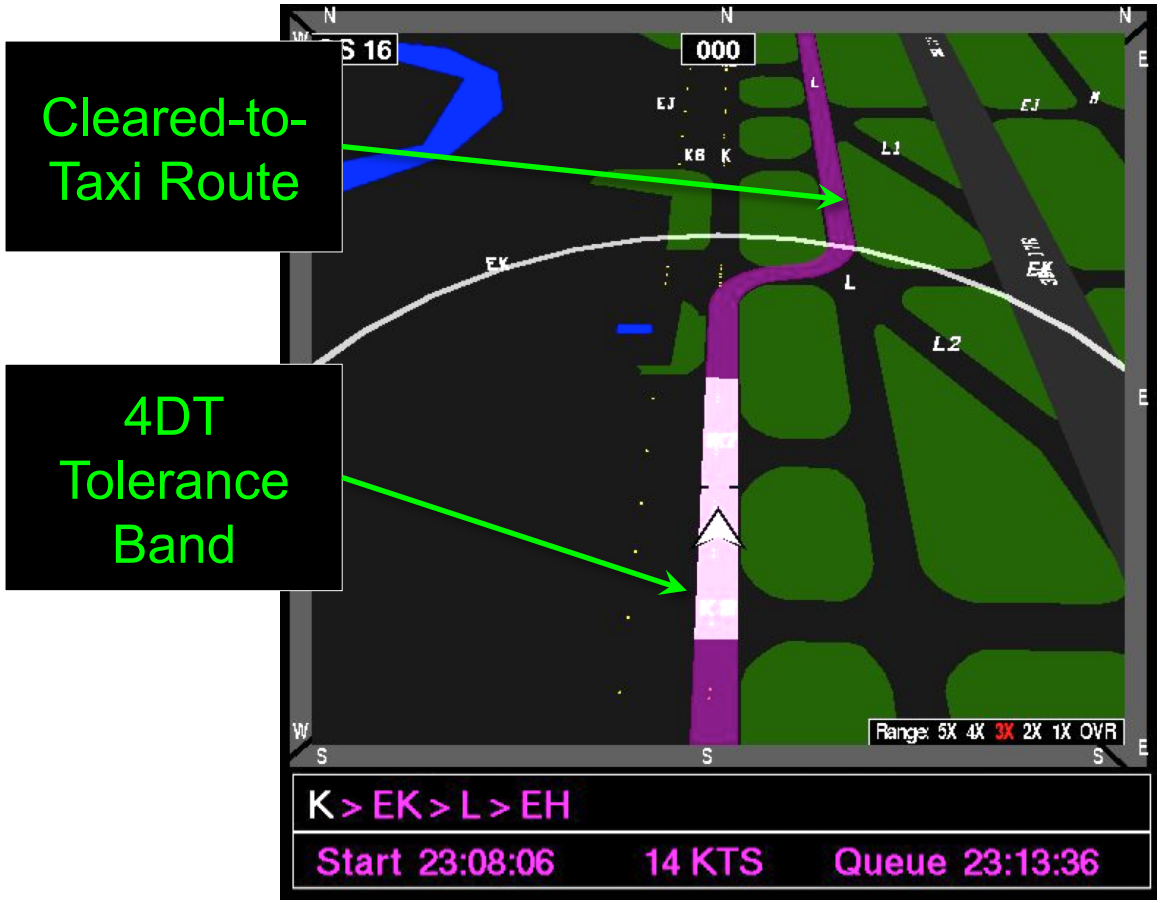




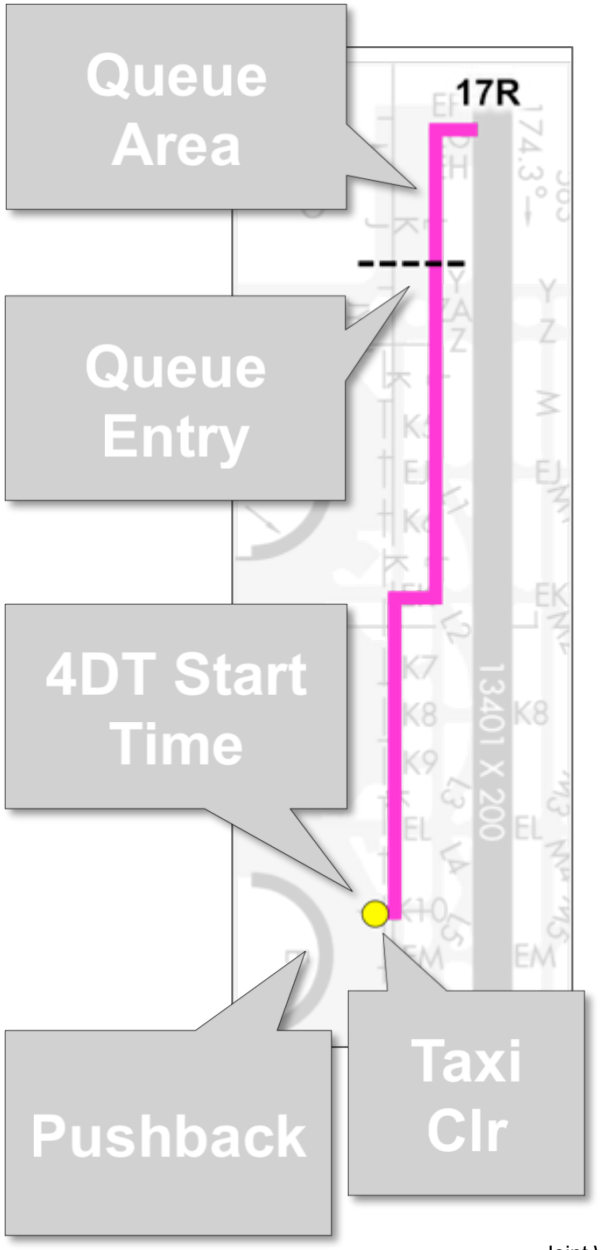
Flight Deck 4DT Proof-of-Concept Study (2014)



- 4DT straightaway speed held constant during each trial.



Flight Deck 4DT Proof-of-Concept Study (2014)

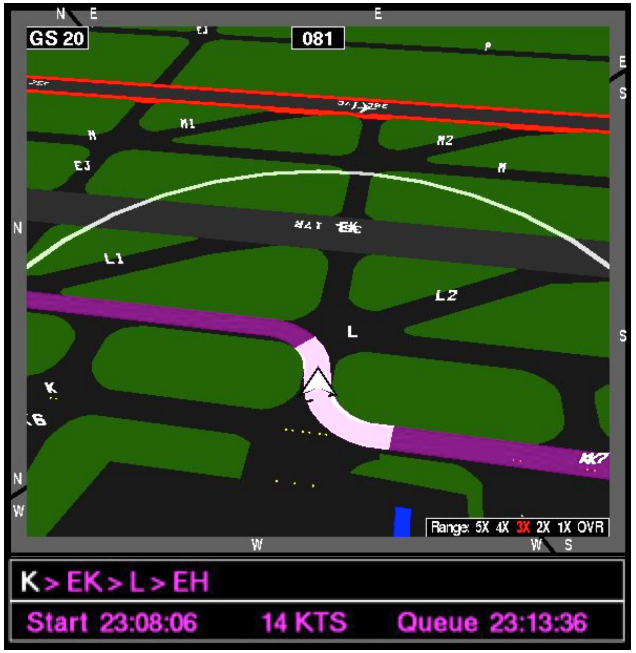


- 4DT speed in turns was 10 kts.
- Distance-based tolerance band.

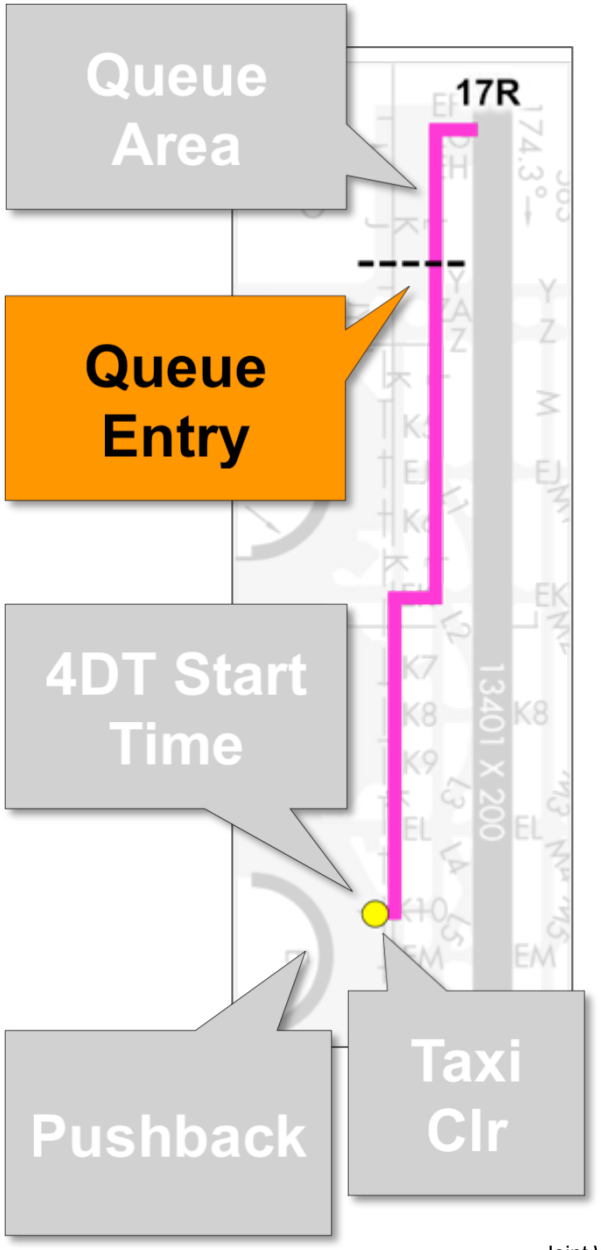
Decelerate
14 kts → 10 kts
@ 1 kt per sec

Turn
10 kts

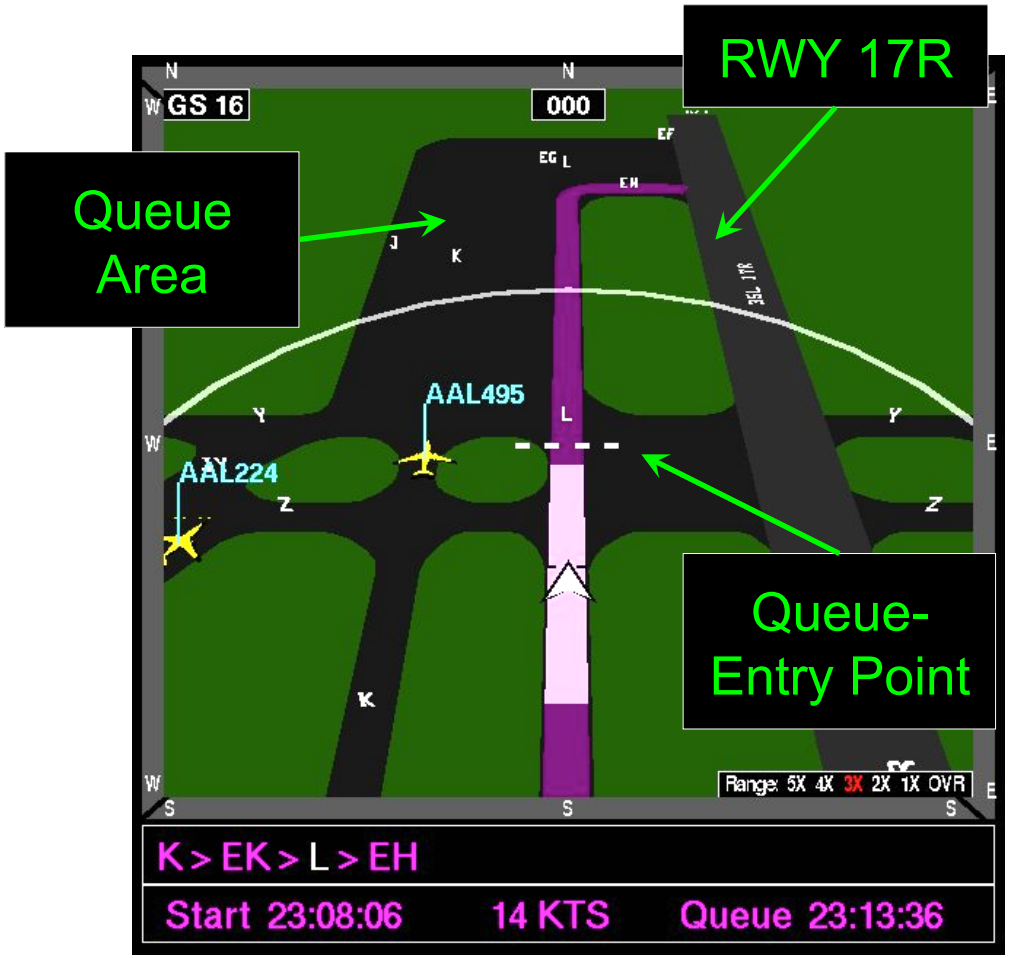
Accelerate
10 kts → 14 kts
@ 1 kt per sec



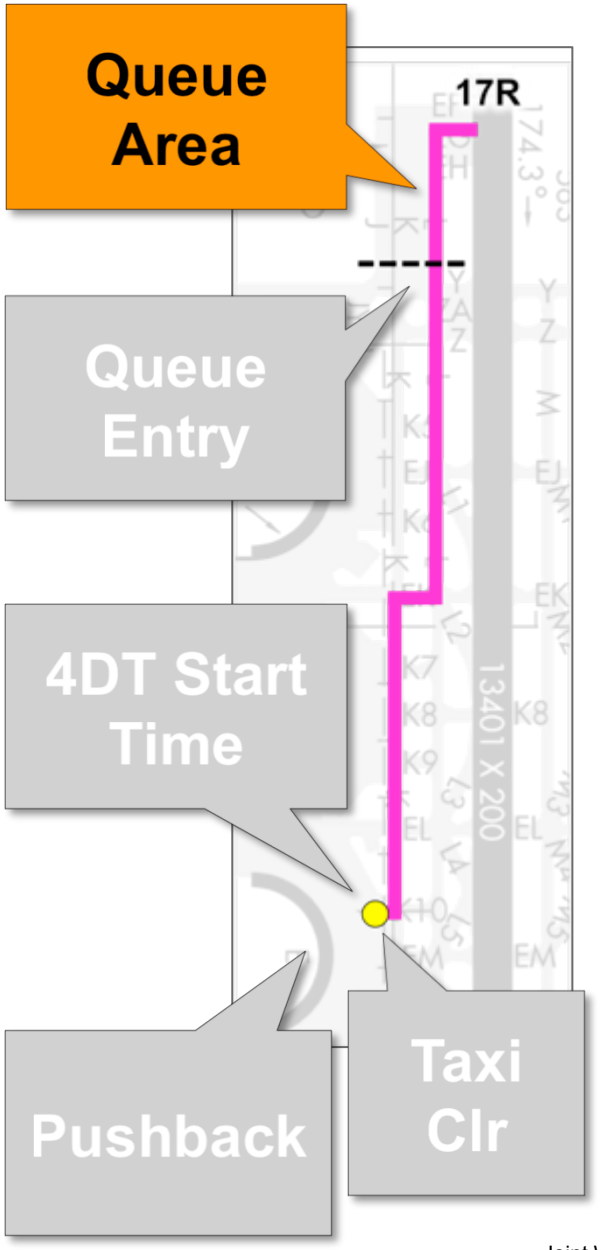
Flight Deck 4DT Proof-of-Concept Study (2014)



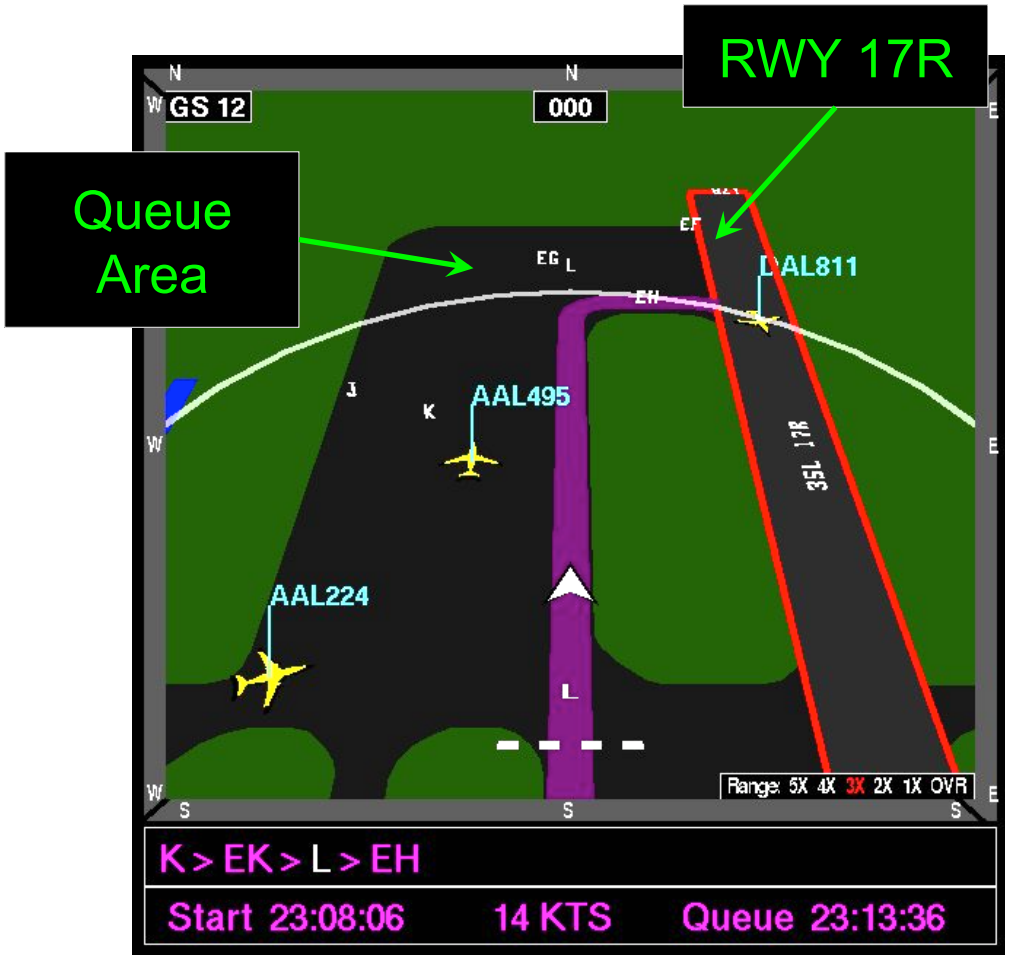
- End of 4DT taxi route at the queue-entry point.
- Upon reaching the queue entry, the tolerance band disappeared.



Flight Deck 4DT Proof-of-Concept Study (2014)

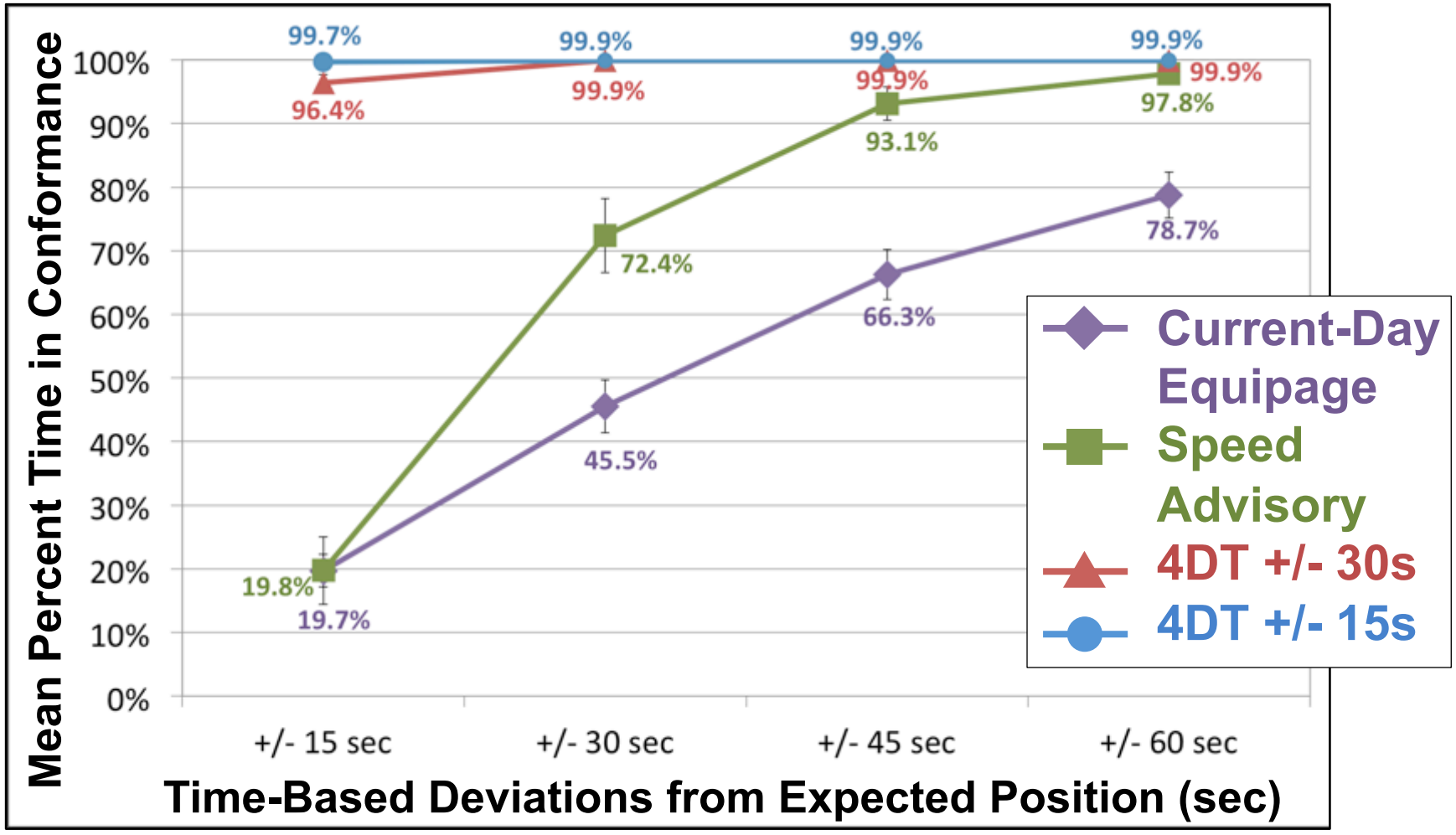


- Pilot enters the queue area at a safe speed and lines up behind any aircraft at the runway hold line.



Flight Deck 4DT Proof-of-Concept Study (2014)

- A verbal speed command, alone, may not support adequate 4DT conformance along the taxi route.
- Flight deck display required to aid pilots in conforming to the 4DT.



Flight Deck 4DT Proof-of-Concept Study (2014)

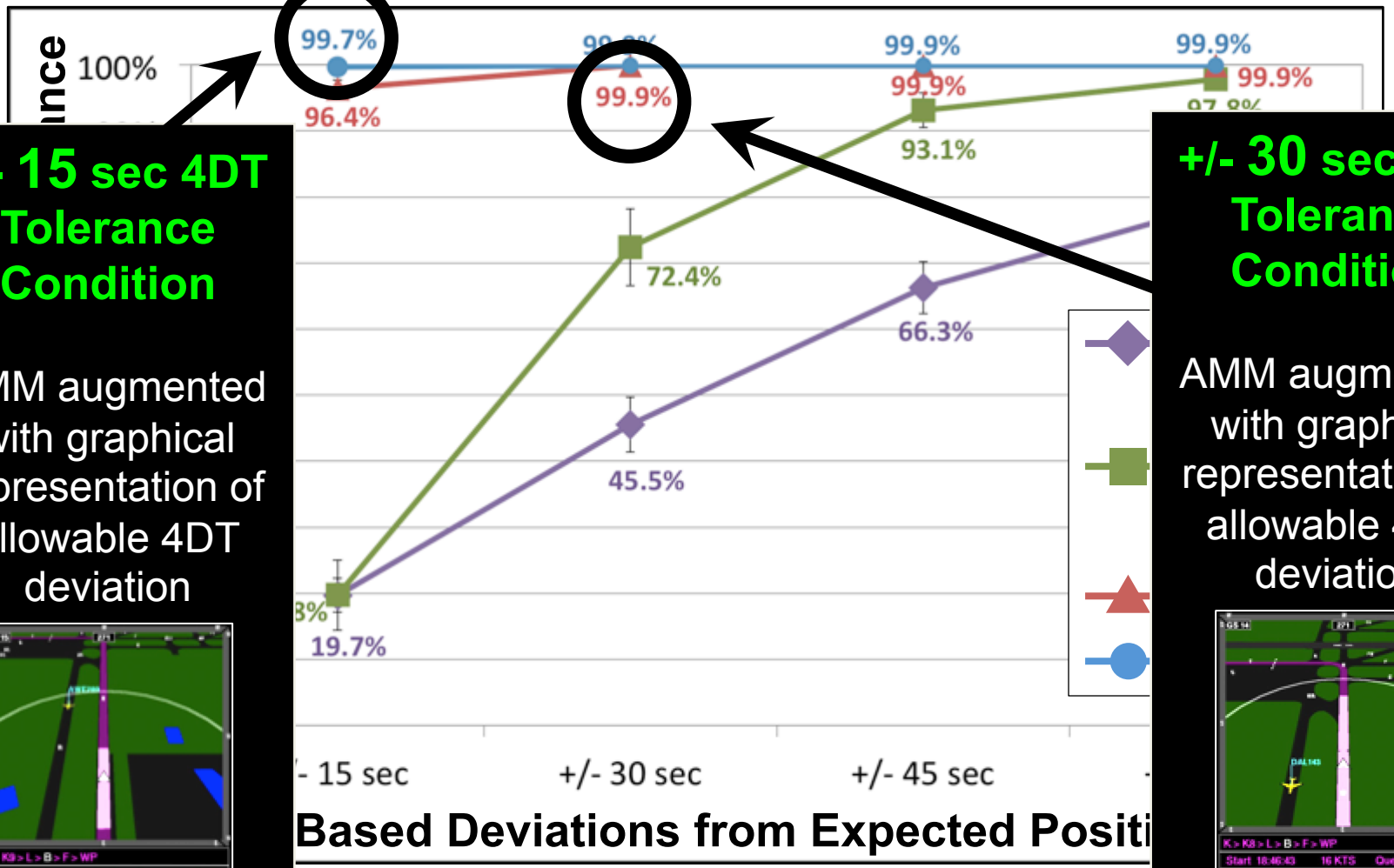
- A verbal speed command, alone, may not support adequate 4DT conformance along the taxi route.
- Flight deck display required to aid pilots in conforming to the 4DT.

+/- 15 sec 4DT Tolerance Condition

AMM augmented with graphical representation of allowable 4DT deviation

Flight Deck 4DT Proof-of-Concept Study (2014)

- A verbal speed command, alone, may not support adequate 4DT conformance along the taxi route.
- Flight deck display required to aid pilots in conforming to the 4DT.



+/- 15 sec 4DT Tolerance Condition

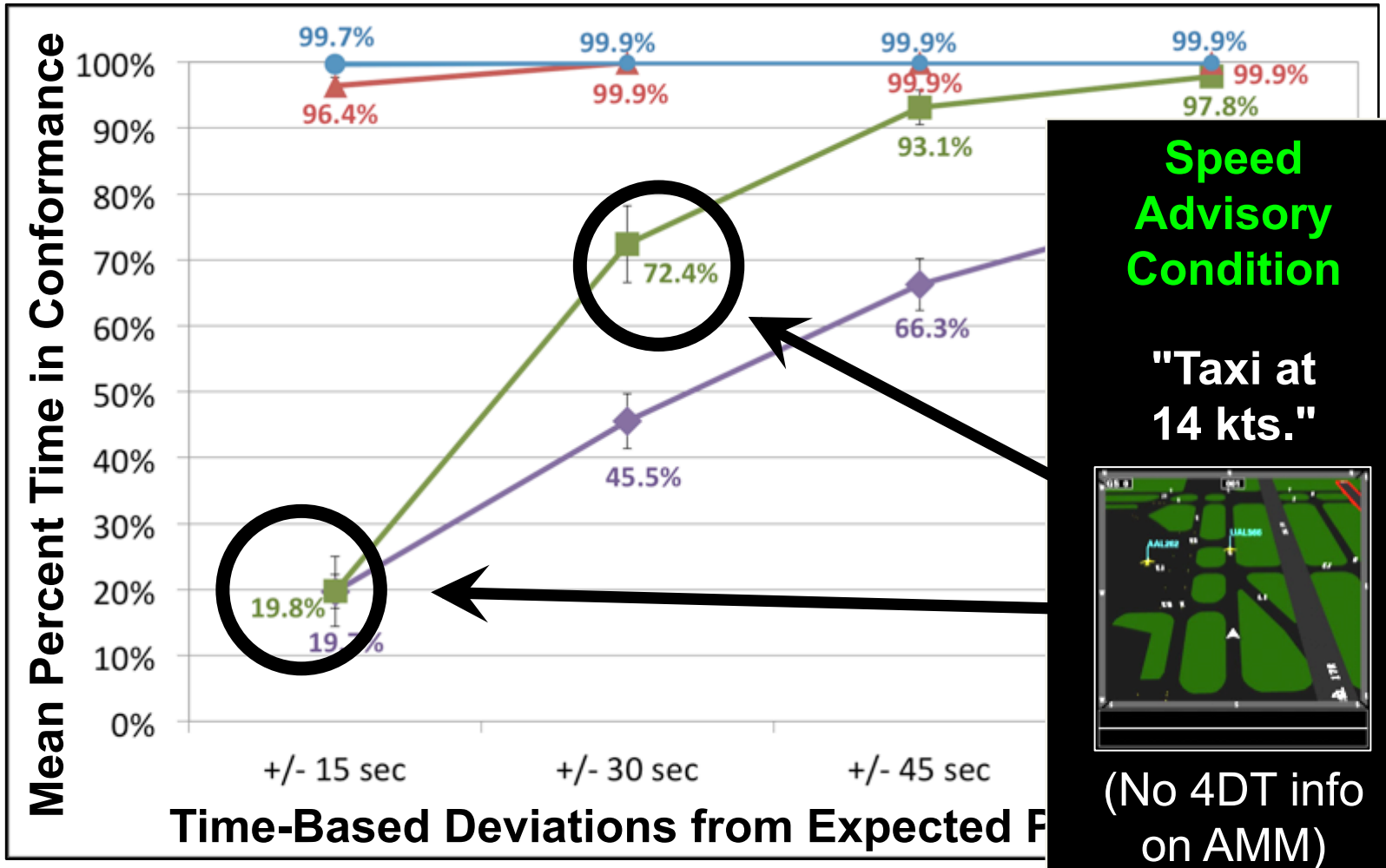
AMM augmented with graphical representation of allowable 4DT deviation

+/- 30 sec 4DT Tolerance Condition

AMM augmented with graphical representation of allowable 4DT deviation

Flight Deck 4DT Proof-of-Concept Study (2014)

- A verbal speed command, alone, may not support adequate 4DT conformance along the taxi route.
- Flight deck display required to aid pilots in conforming to the 4DT.



Flight Deck Pilot-in-the-Loop 4DT Studies
Human-Centered Systems Lab (HCSL)

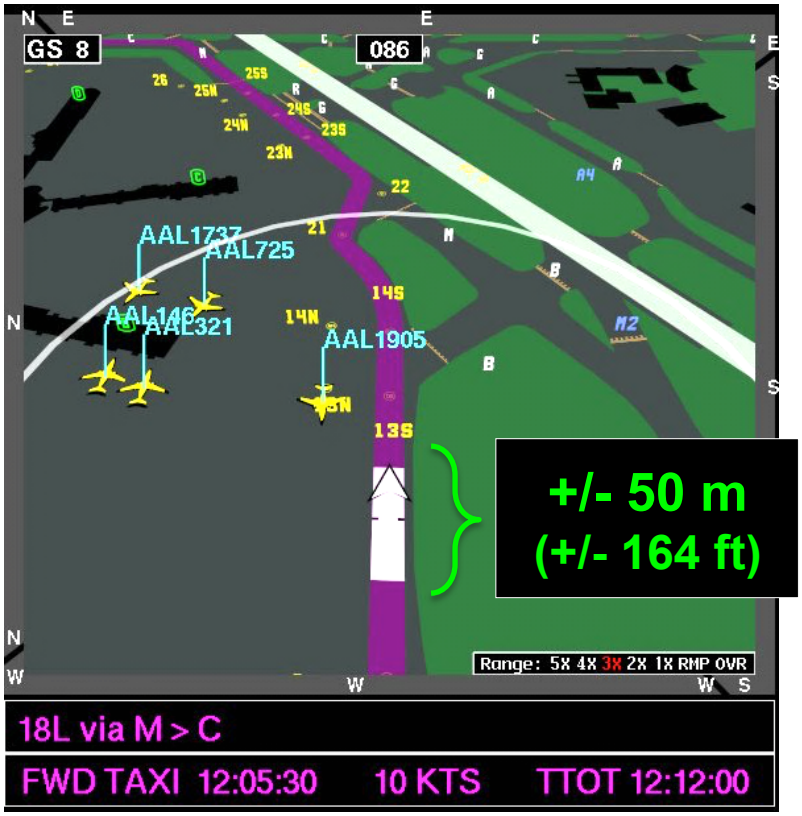
	Proof-of-Concept Study (2014)	4DT Display Comparison Study (2016)
Allowable 4DT Deviation Band	Time-Based Band	Distance-Based Band
4DT Straightaway Speed	Held constant within each trial	4DT Speed Changes Mid-Taxi
4DT Speeds	14, 15, or 16 kts	Range of Realistic Taxi Speeds 8 kts – 25 kts
Start of 4DT Taxi Route	Ramp Spot	Near the Terminal
Airport	Dallas/Fort Worth Airport (DFW)	Charlotte Douglas Airport (KCLT)

Flight Deck 4DT Display Comparison Study (2016)

	4DT Conformance	Allowable Deviation	Graphical 4DT Indicator	Flight Deck Display
Condition 1 **4DT +/- 50 m**	Defined Conformance	+/- 50 m	Reference Markers with Tolerance Band	
Condition 2 **4DT +/- 123 m**	Defined Conformance	+/- 123 m	Reference Markers with Tolerance Band	
Condition 3 **4DT Undefined Conformance**	Undefined Conformance	Undefined	Dot (no tolerance indicated)	

Flight Deck 4DT Display Comparison Study (2016)

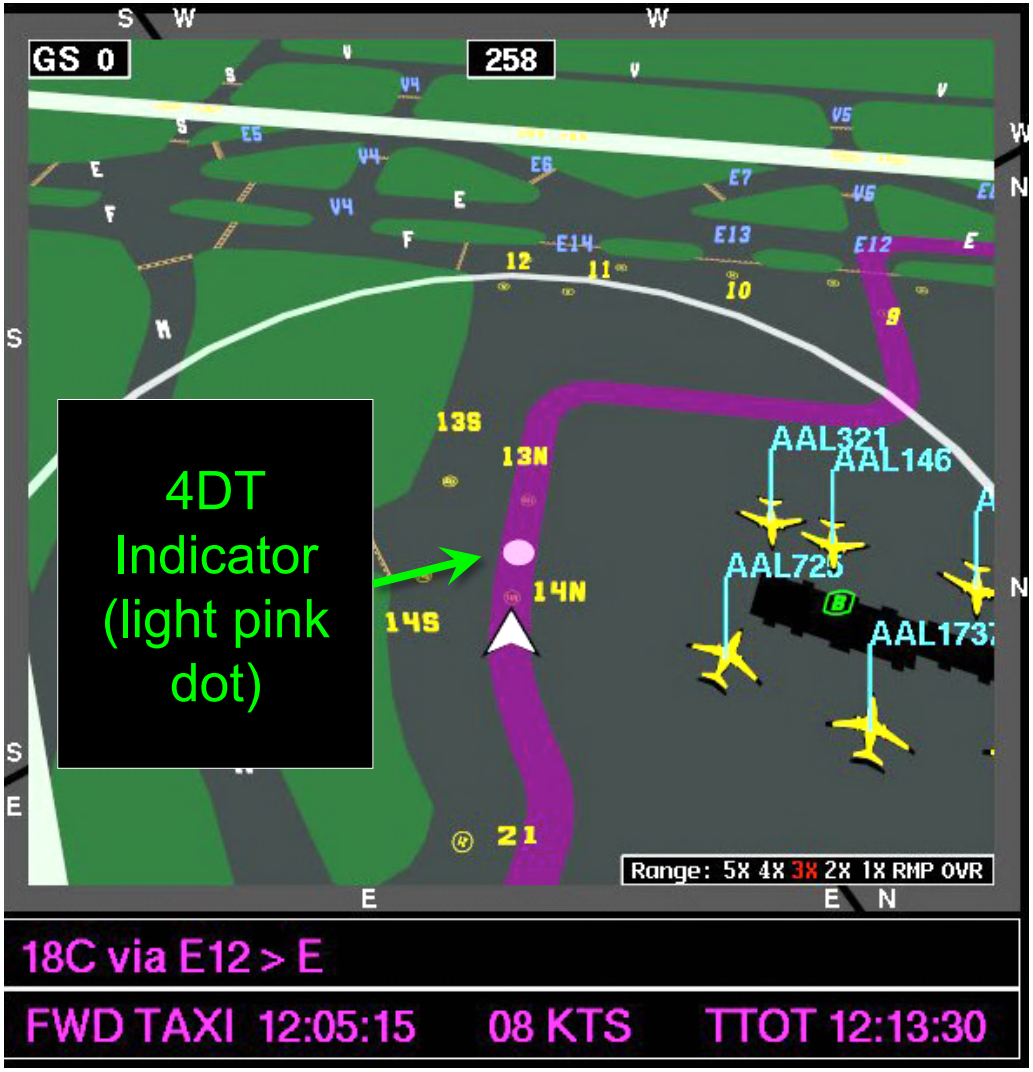
Defined-Tolerance Display Format (Distance-Based Band)



- Defined Tolerance Instructions:
  - You are in compliance with the 4DT clearance when the ownship icon is within the tolerance band.
  - No need to track the 4DT reference markers precisely.

Flight Deck 4DT Display Comparison Study (2016)

Undefined-Tolerance Display Format



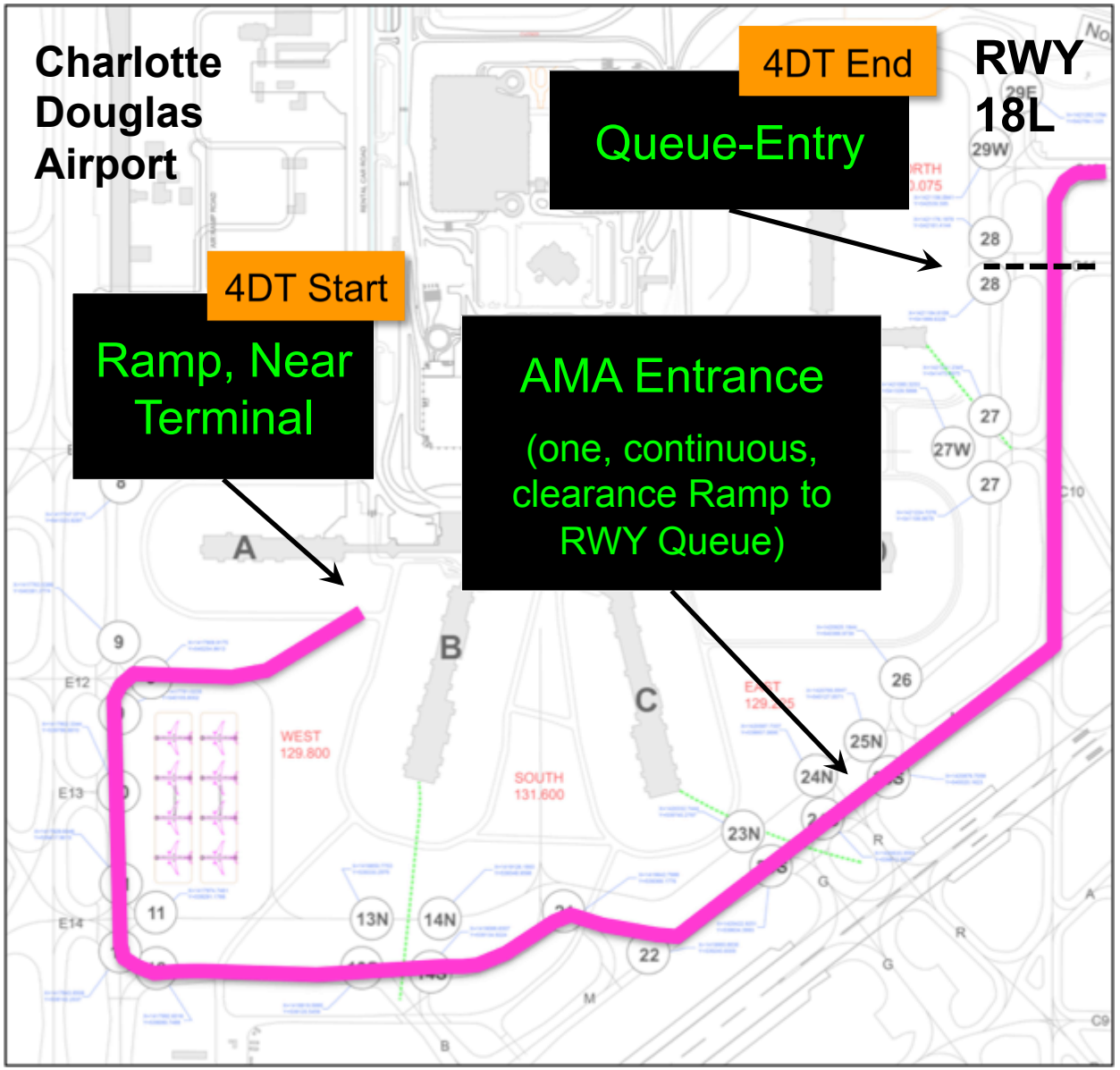
- 4DT indicator: Light pink dot.
- Allowable tolerance was undefined.
- Undefined tolerance display format instructions:
  - "You decide how “close is close enough” to taxi to the dot and you can taxi ahead of, or behind, the 4DT dot."
- Pilots defined conformance as they saw fit.
- No need to track the 4DT indicator (dot) precisely.

Flight Deck 4DT Display Comparison Study (2016)

4DT Acceleration /Deceleration Rate
1 kt per sec

Beginning of 4DT Taxi
4DT Speed Changes
14 kt turn in the AMA

Turn Speed = 14 kts in the AMA



Flight Deck 4DT Display Comparison Study (2016)

4DT Speed Changes

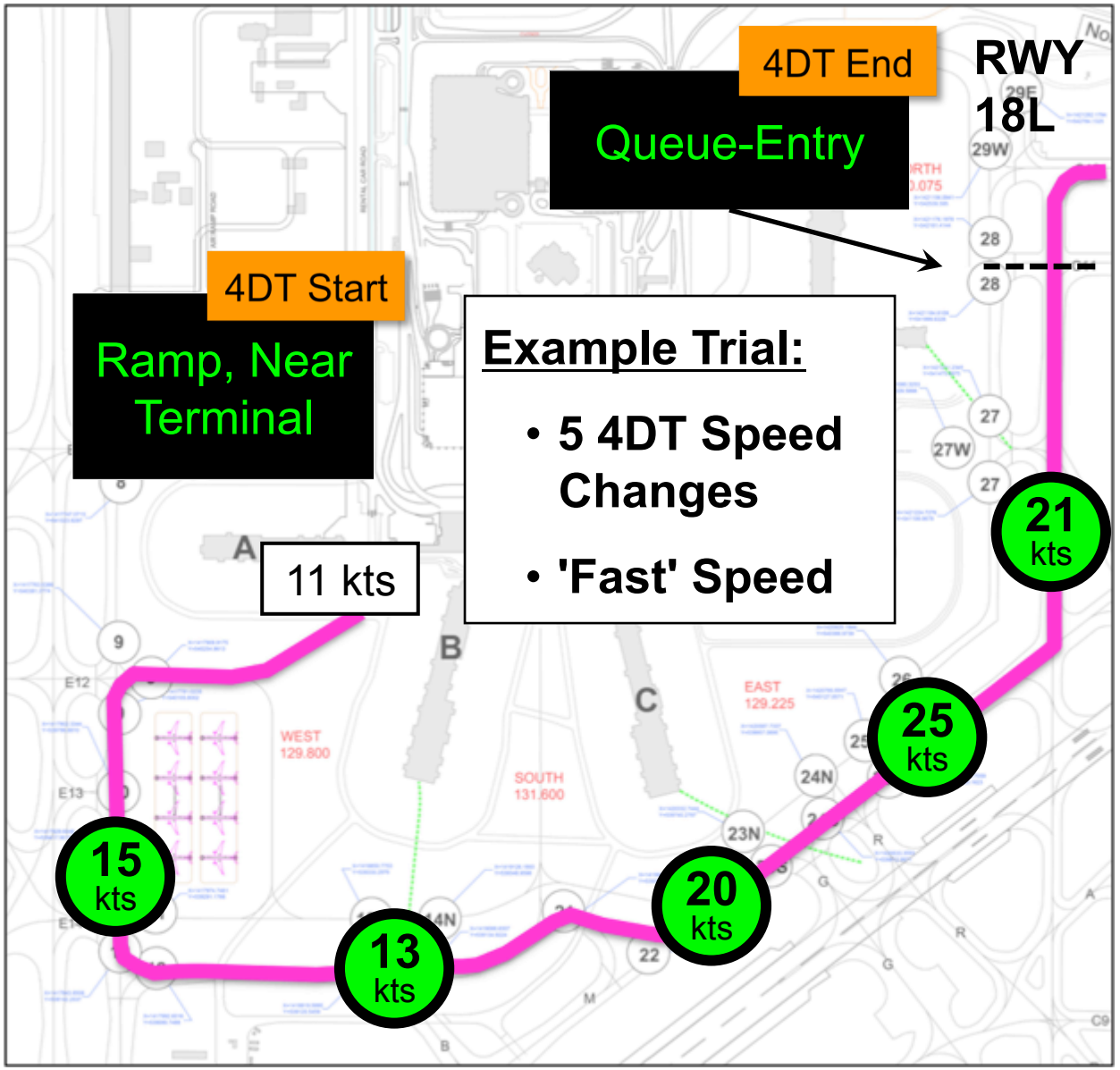
2 or 5 per Trial

4DT Speeds

8 kts – 25 kts

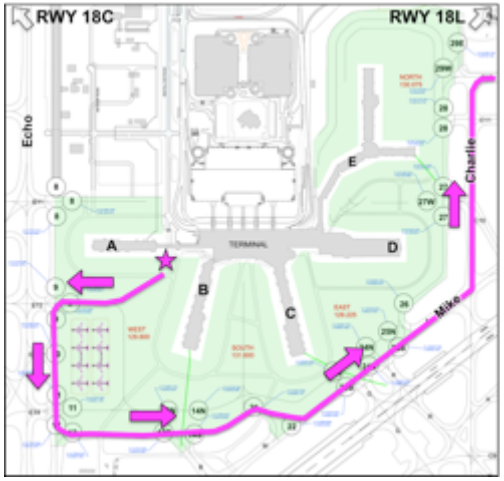
'Slow' or 'Fast' Average Speed

	Ramp	AMA
Slow	10 kts	16 kts
Fast	13 kts	22 kts

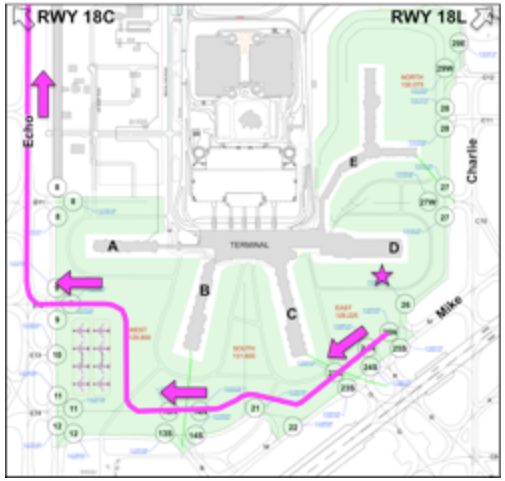


Flight Deck 4DT Display Comparison Study (2016)

- Charlotte Douglas Airport (KCLT)
- 12 Pilots
- Experimenter First Officer
  - assisted with navigation, DataComm
- 12 experimental trials
  - 3 4DT Display Formats:
    - blocked and counterbalanced
  - practice trial before each block
- Taxi Routing for Aircraft: Creation and Controlling (TRACC) (DLR)
  - prototype surface management system
  - parameters from simulation analysis
  - two or five speed changes
  - +/- 50 m (smaller tolerance band)



Route 1

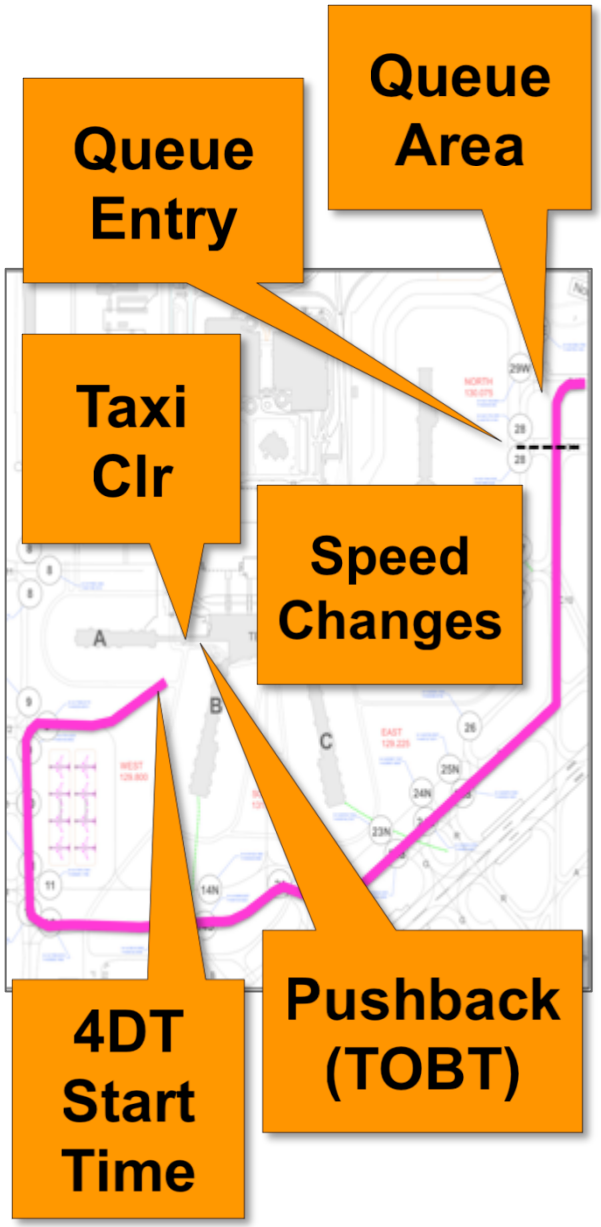


Route 2

Avg. 4DT Speed	4DT Speed Changes	Ramp				Airport Movement Area (AMA)			
		Taxi Segment				*Taxi Segment*			
		1	*2*	*3*	*Avg.*	*1*	*2*	*3*	*Avg.*
Slow	2	11	9	-	**10**	16	-	-	**16**
Slow	5	11	8	11	**10**	14	19	15	**16**
Fast	2	11	15	-	**13**	22	-	-	**22**
Fast	5	11	15	13	**13**	20	25	21	**22**

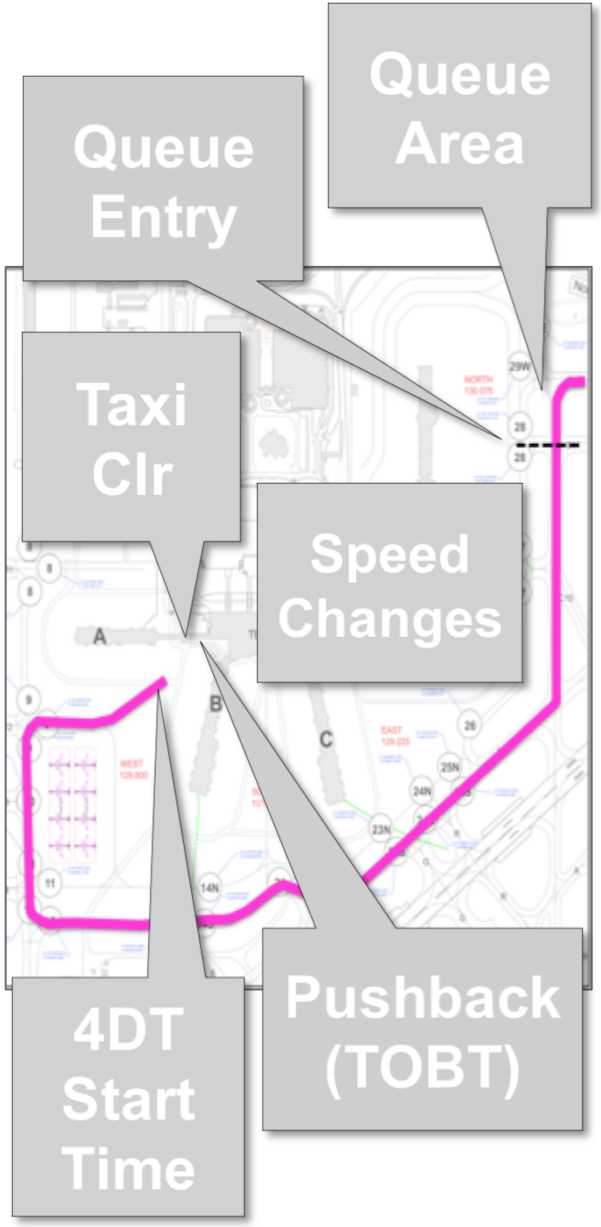
- These four trials repeated in each of the three 4DT Display Format conditions.

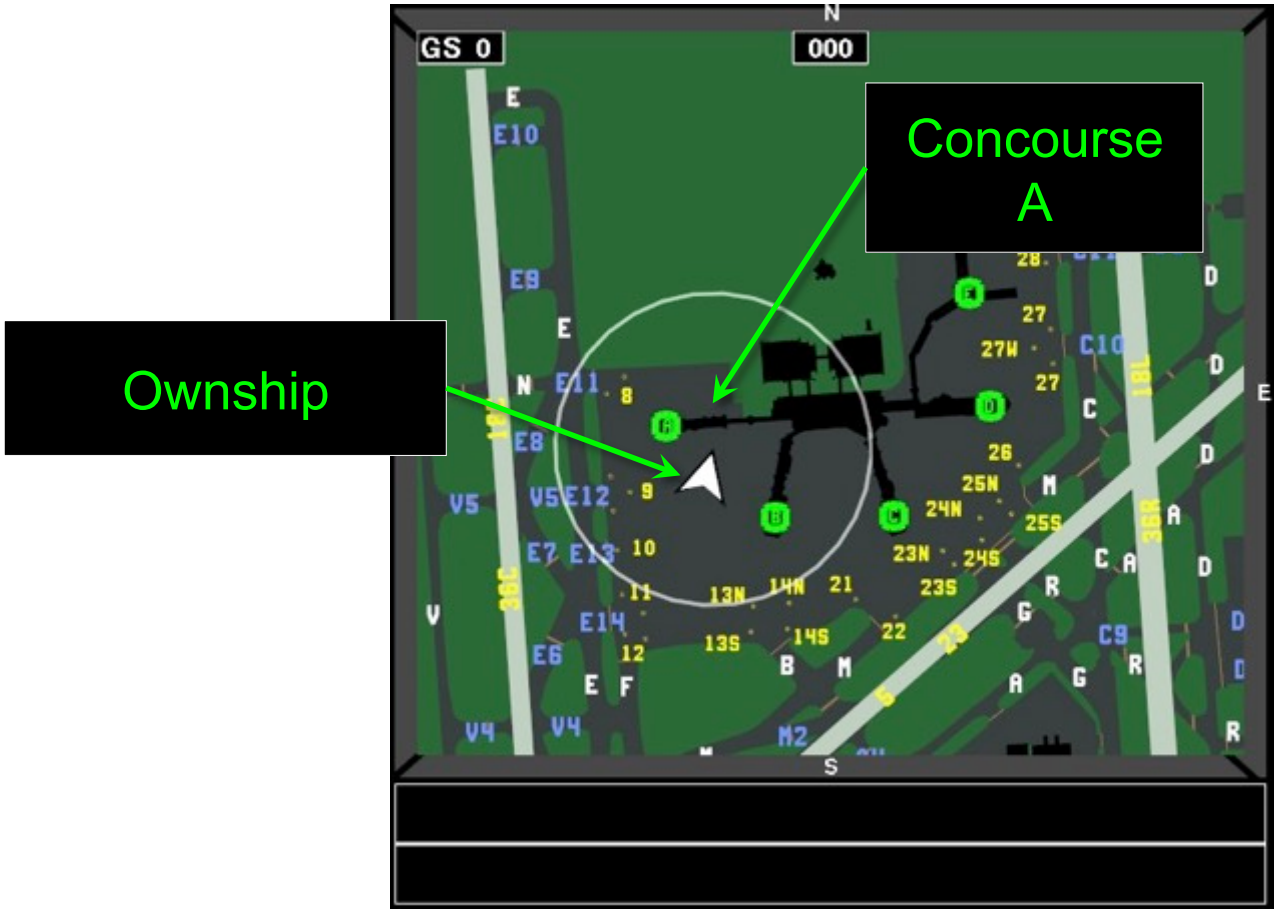
Flight Deck 4DT Display Comparison Study (2016)



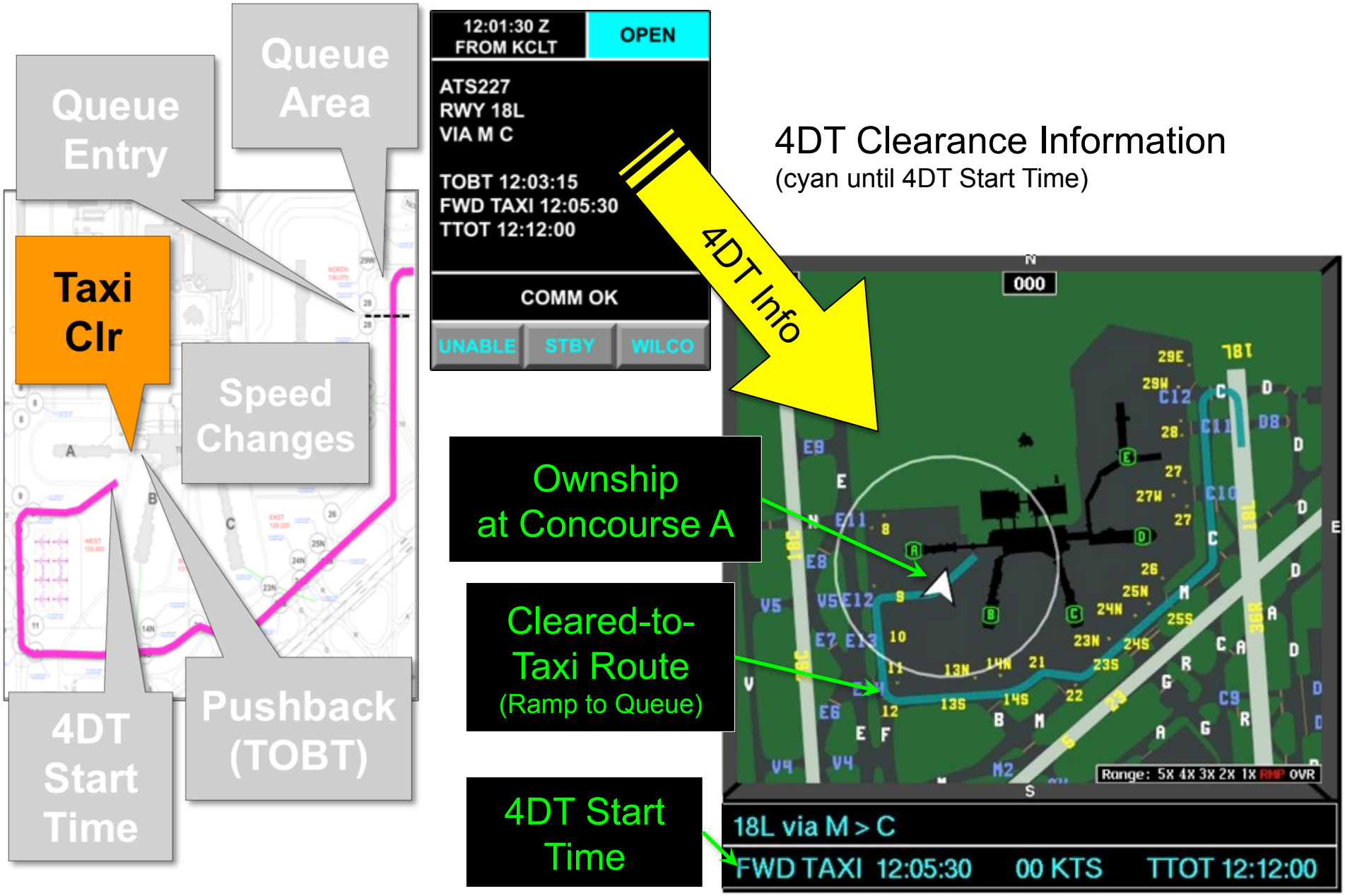
Example Trial

Flight Deck 4DT Display Comparison Study (2016)

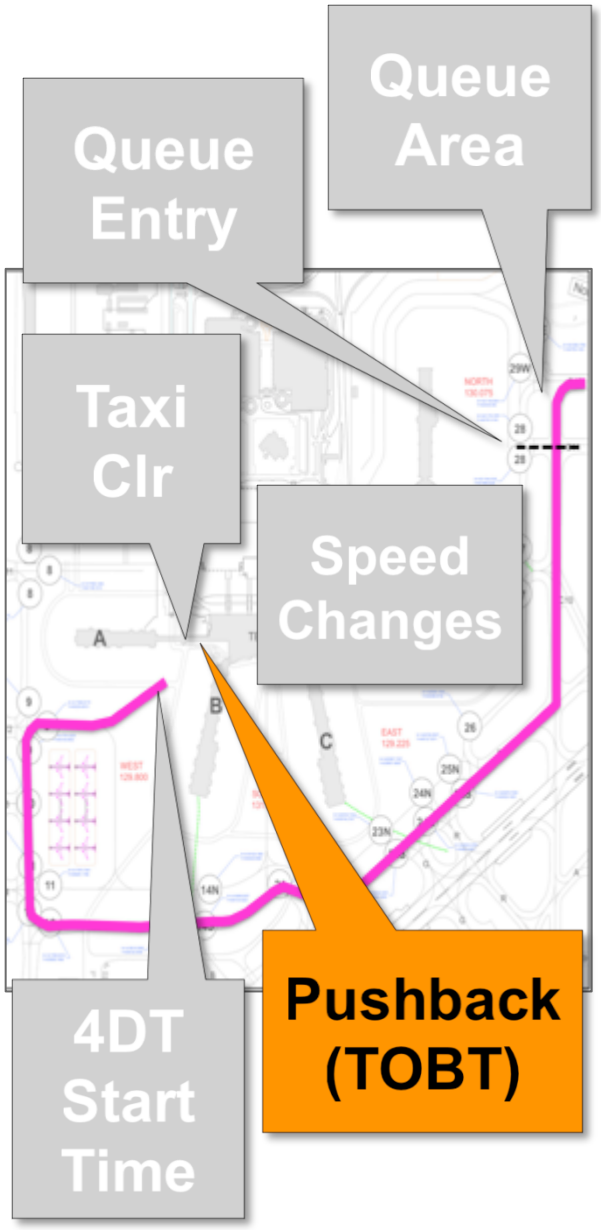


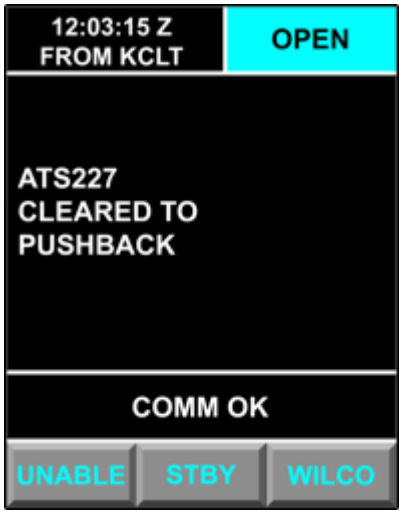


Flight Deck 4DT Display Comparison Study (2016)



Flight Deck 4DT Display Comparison Study (2016)





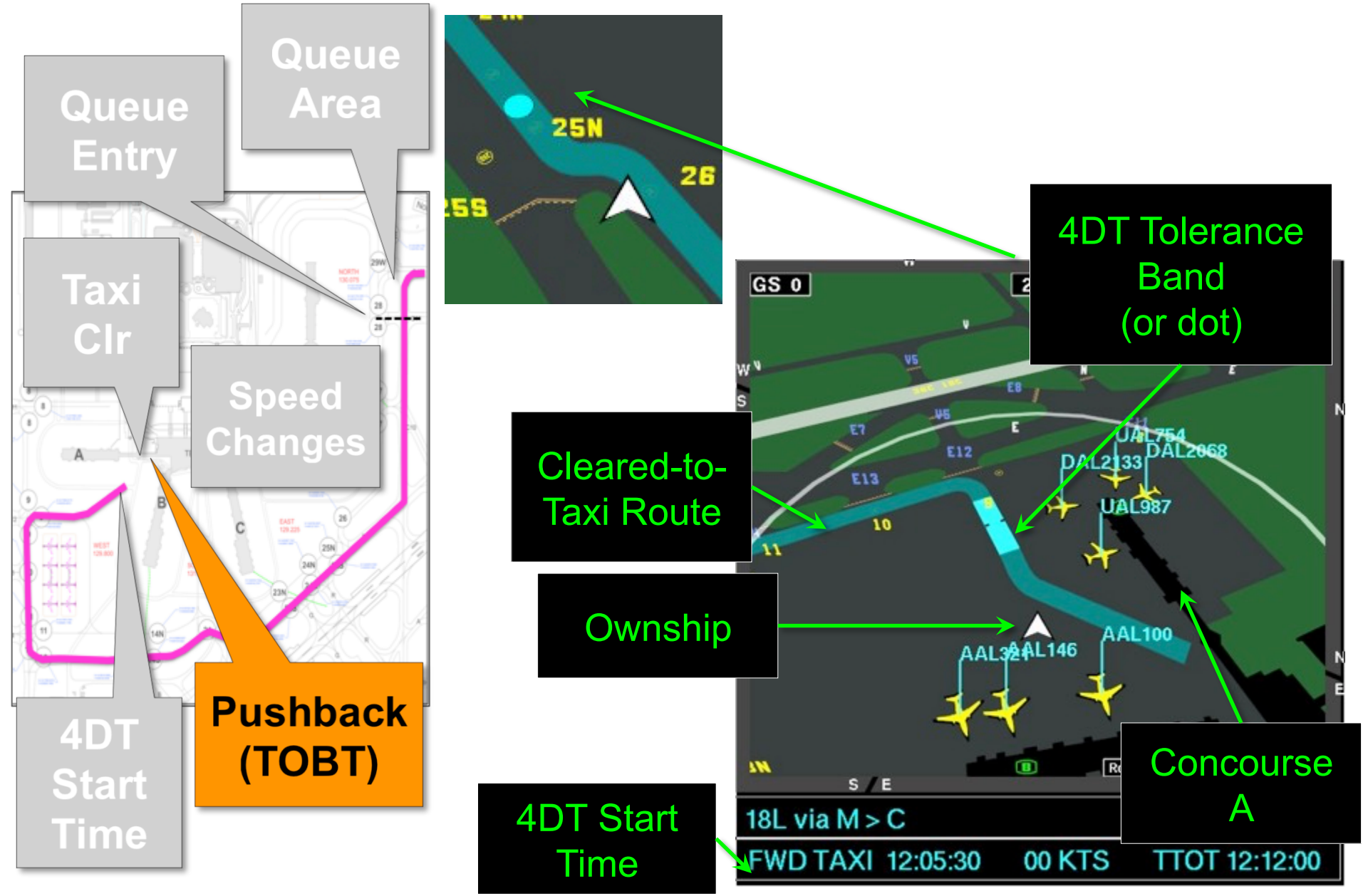
- At Target Off-Block Time (TOBT)

Ownship at Concourse A

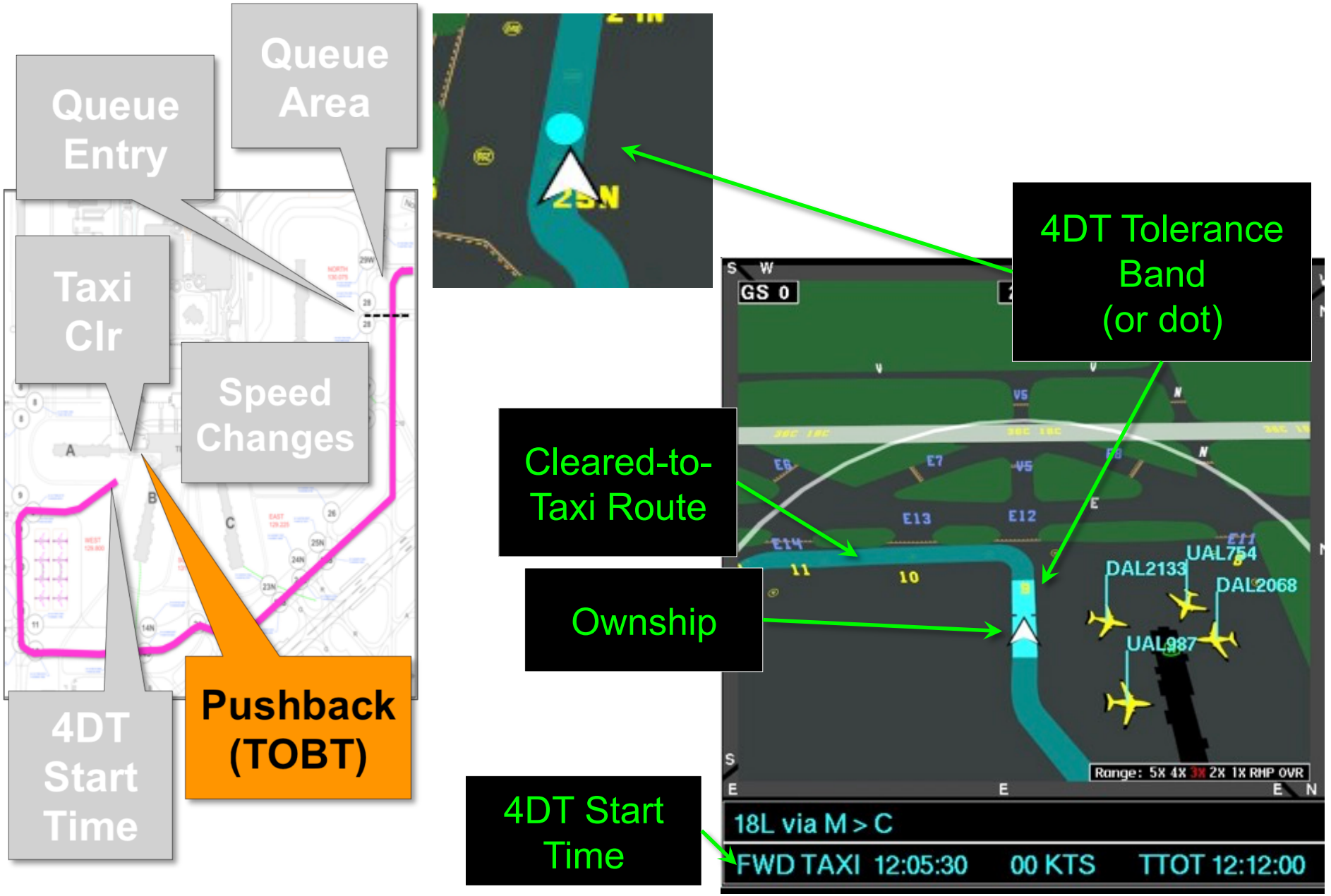
Cleared-to-Taxi Route (Ramp to Queue)

4DT Start Time

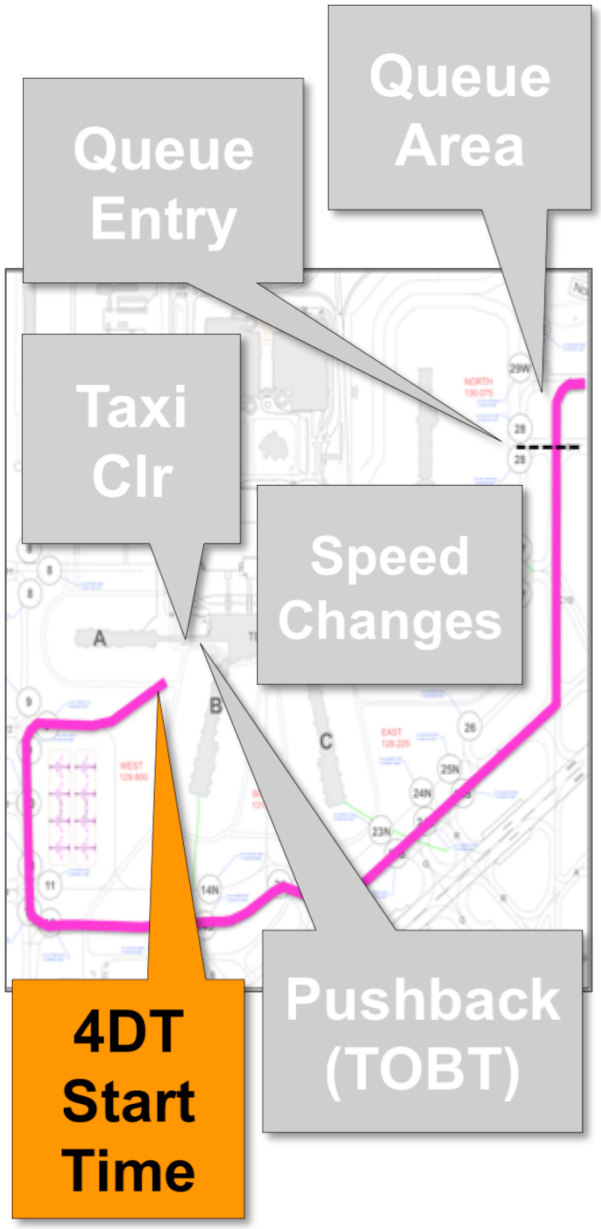
Flight Deck 4DT Display Comparison Study (2016)



Flight Deck 4DT Display Comparison Study (2016)



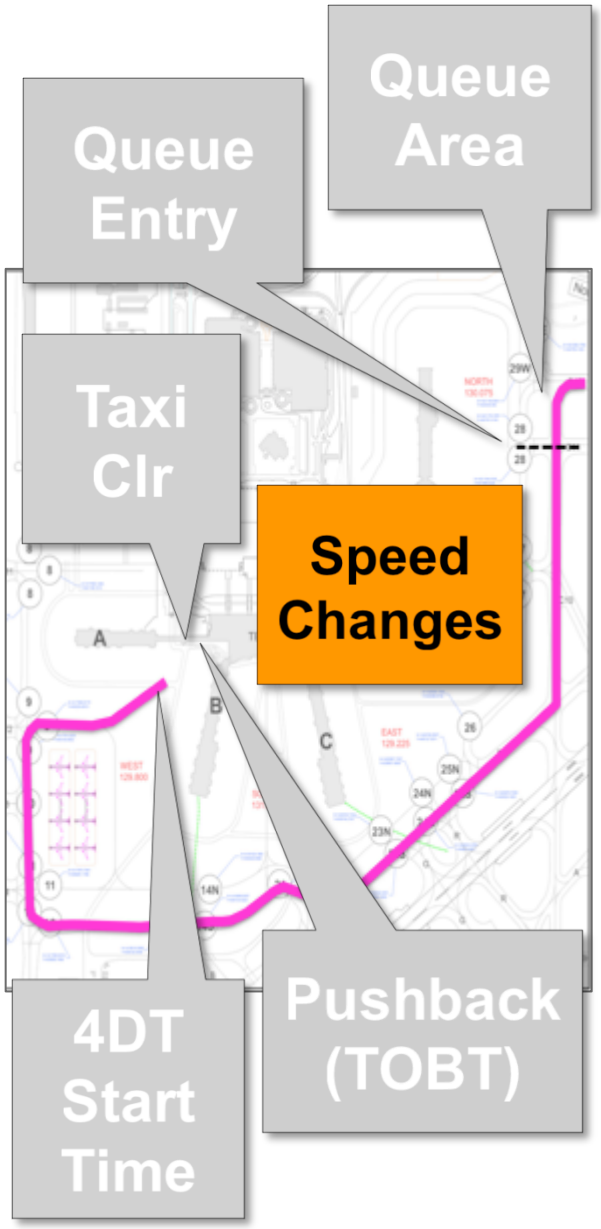
Flight Deck 4DT Display Comparison Study (2016)



- 4DT Start Time (defined by the 4DT speed profile).
- Auditory Chime and 4DT information turns magenta.
- Pilot begins to taxi.
- 4DT tolerance band (or dot) accelerates from 0 kts to 11 kts at 1 kt per sec.

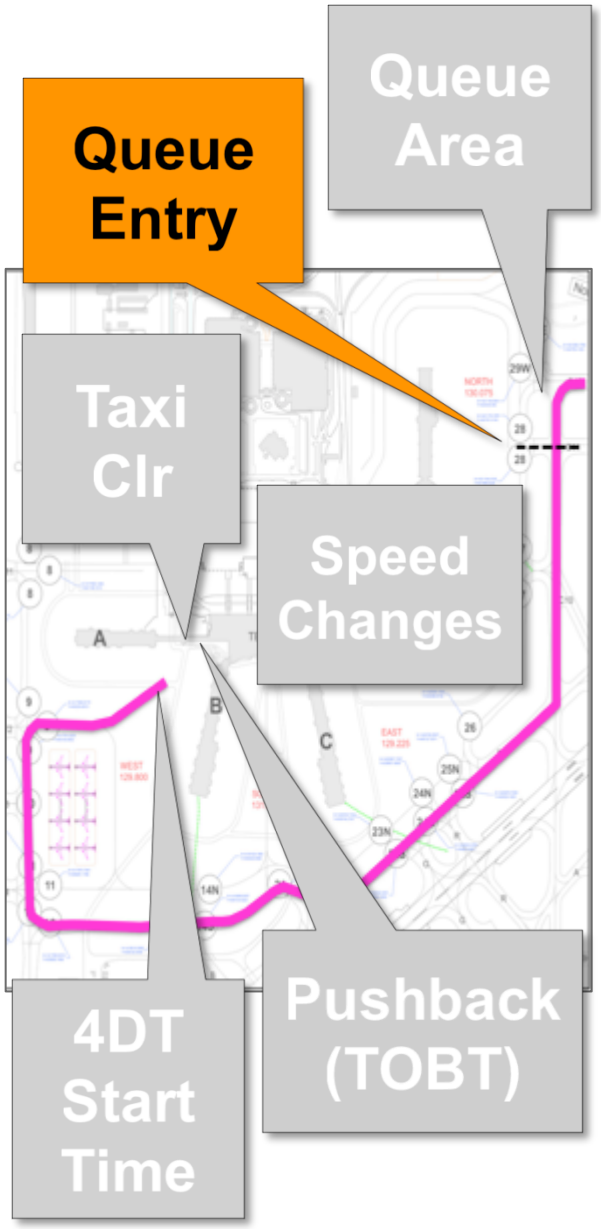
4DT Start Time

Flight Deck 4DT Display Comparison Study (2016)

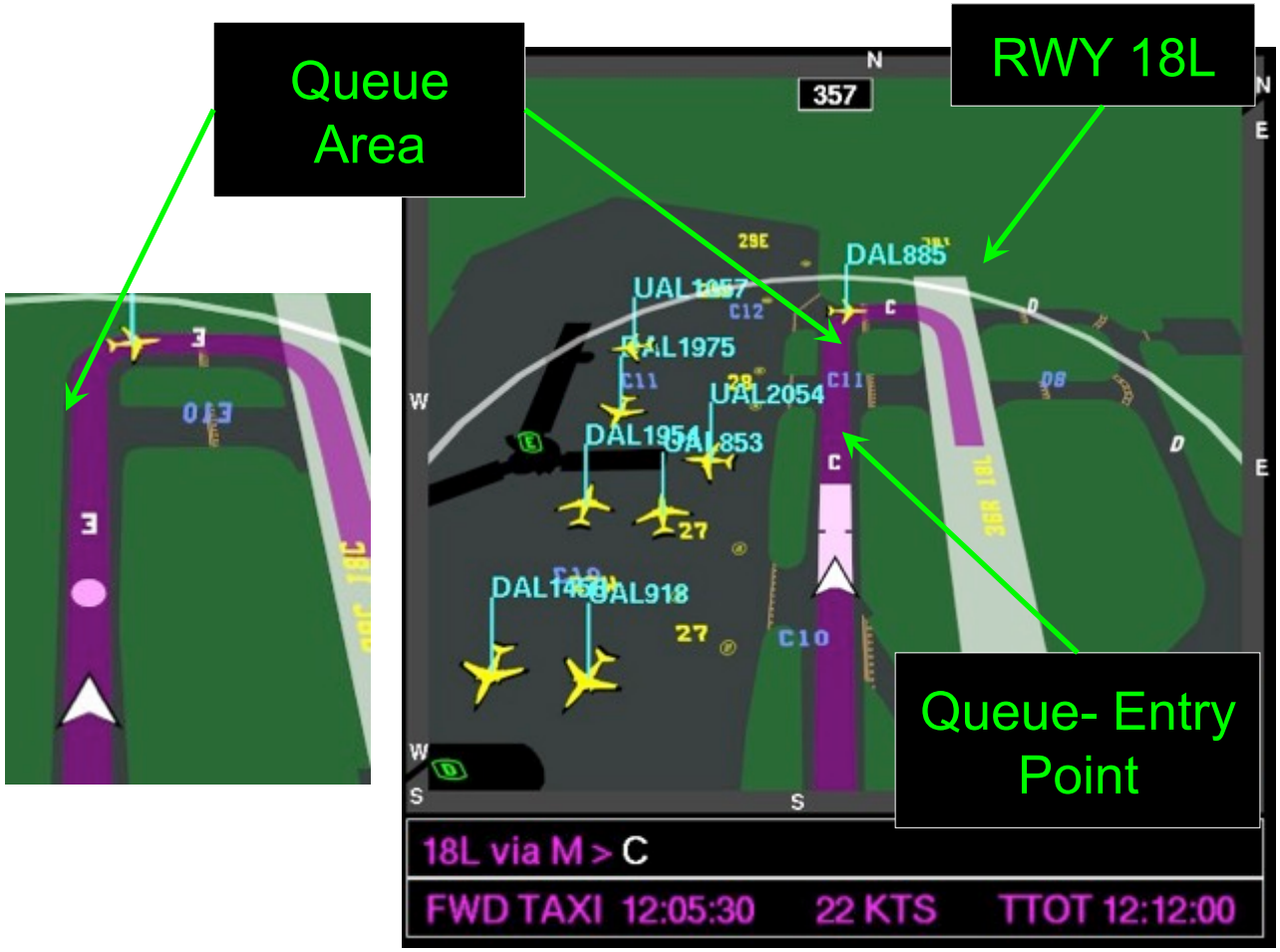


- 4DT speed changes were accompanied by an auditory tone.
- AMM text display updated.
- First Officer: "Speed Change".
- Two or five speed changes per trial.
- At pre-determined locations.

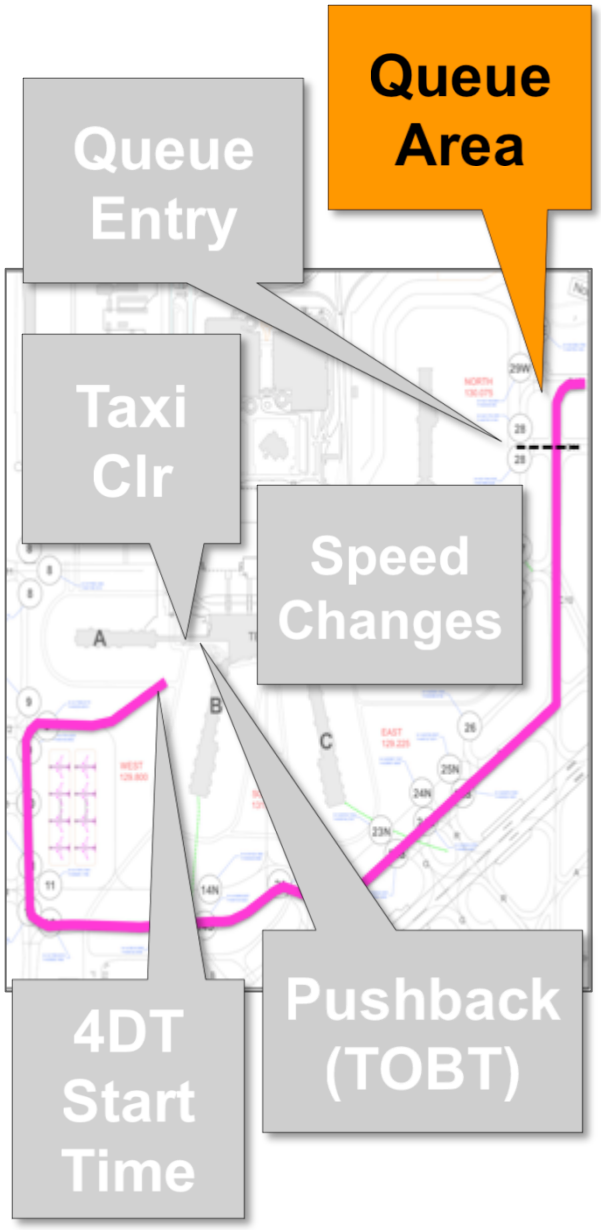
Flight Deck 4DT Display Comparison Study (2016)



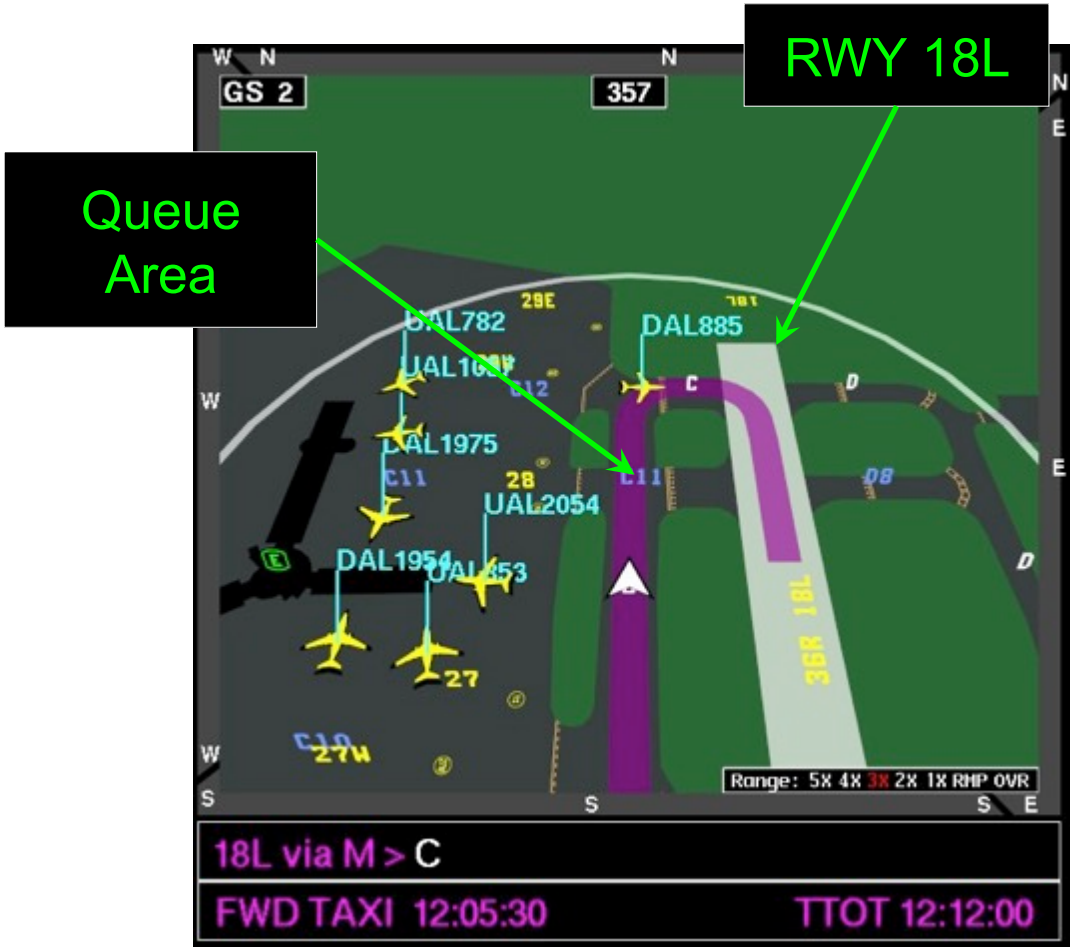
- End of 4DT taxi route at the queue-entry point.
- Upon reaching the queue entry, the tolerance band disappeared.



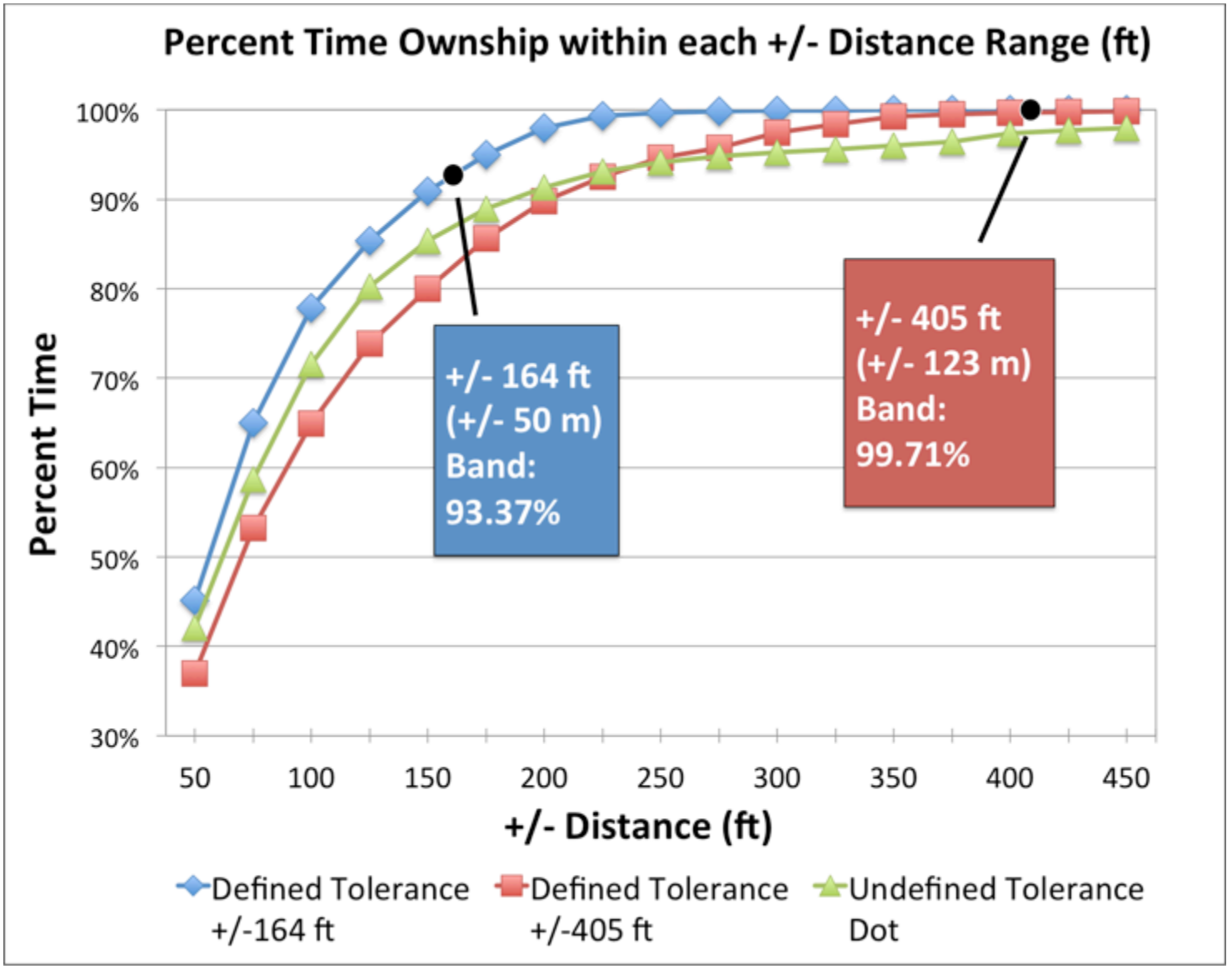
Flight Deck 4DT Display Comparison Study (2016)



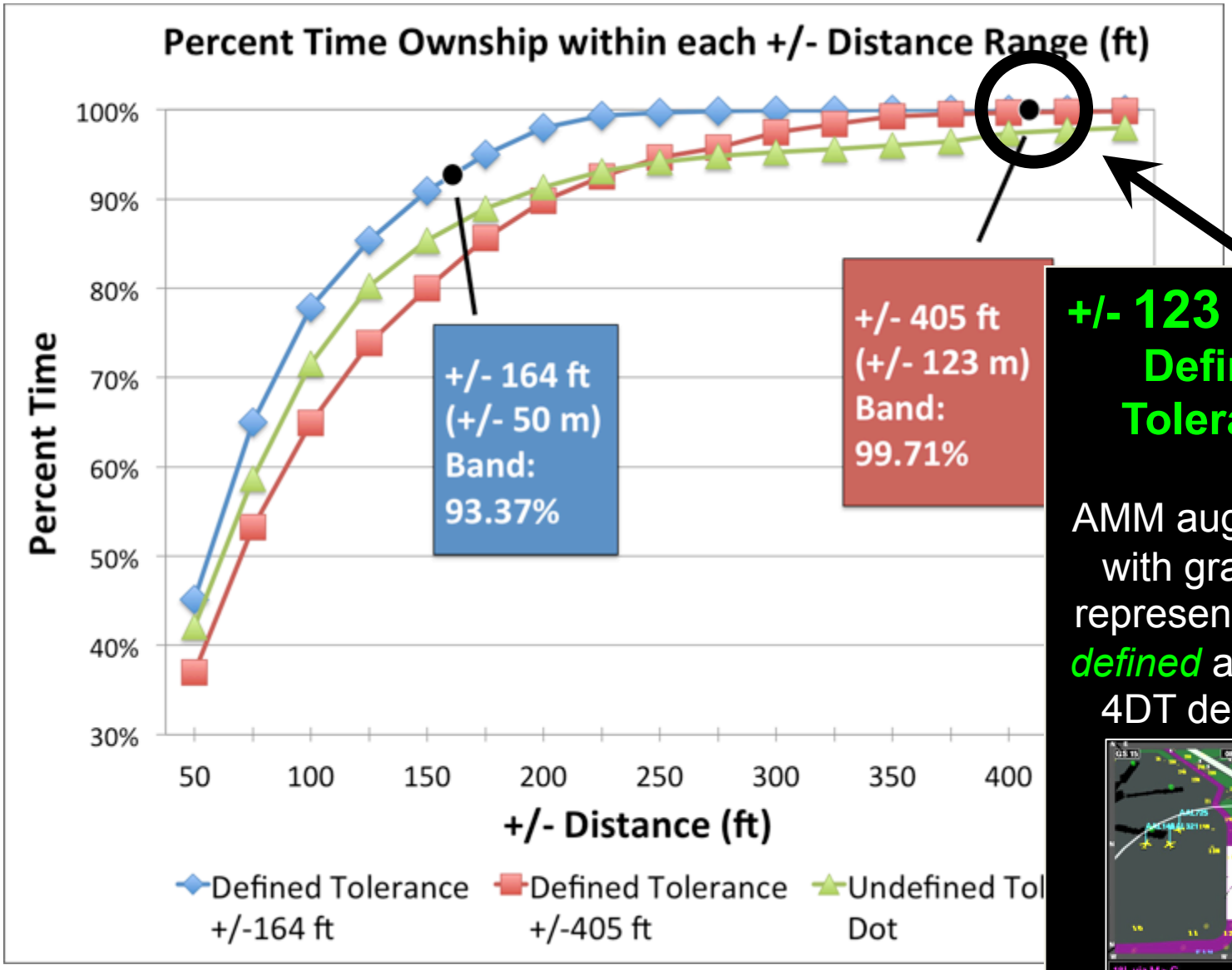
- Pilot enters the queue area at a safe speed and lines up behind any aircraft at the runway hold line.



Flight Deck 4DT Display Comparison Study (2016)



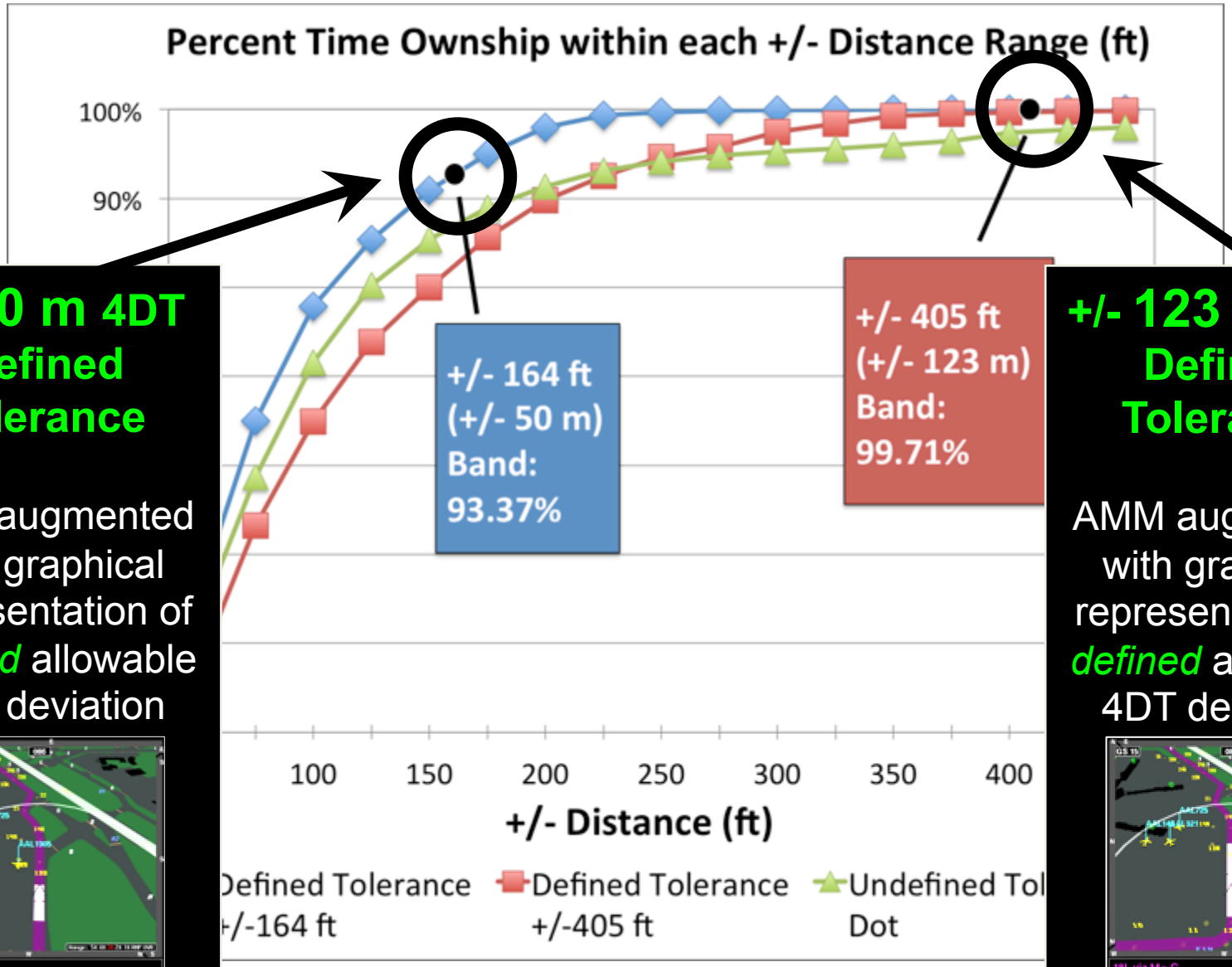
Flight Deck 4DT Display Comparison Study (2016)



+/- 123 m 4DT Defined Tolerance

AMM augmented with graphical representation of *defined* allowable 4DT deviation

Flight Deck 4DT Display Comparison Study (2016)



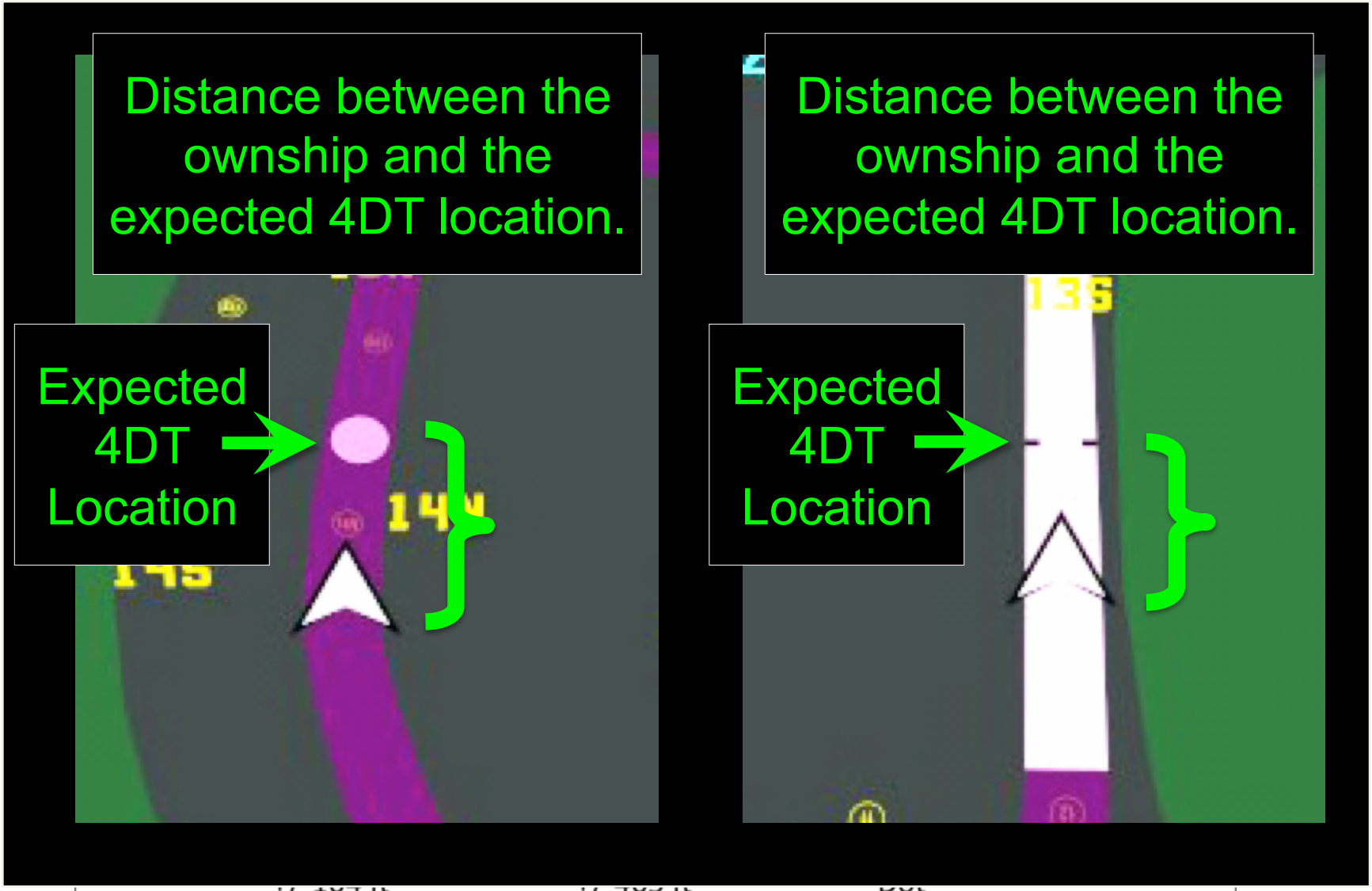
+/- 50 m 4DT Defined Tolerance

AMM augmented with graphical representation of *defined* allowable 4DT deviation

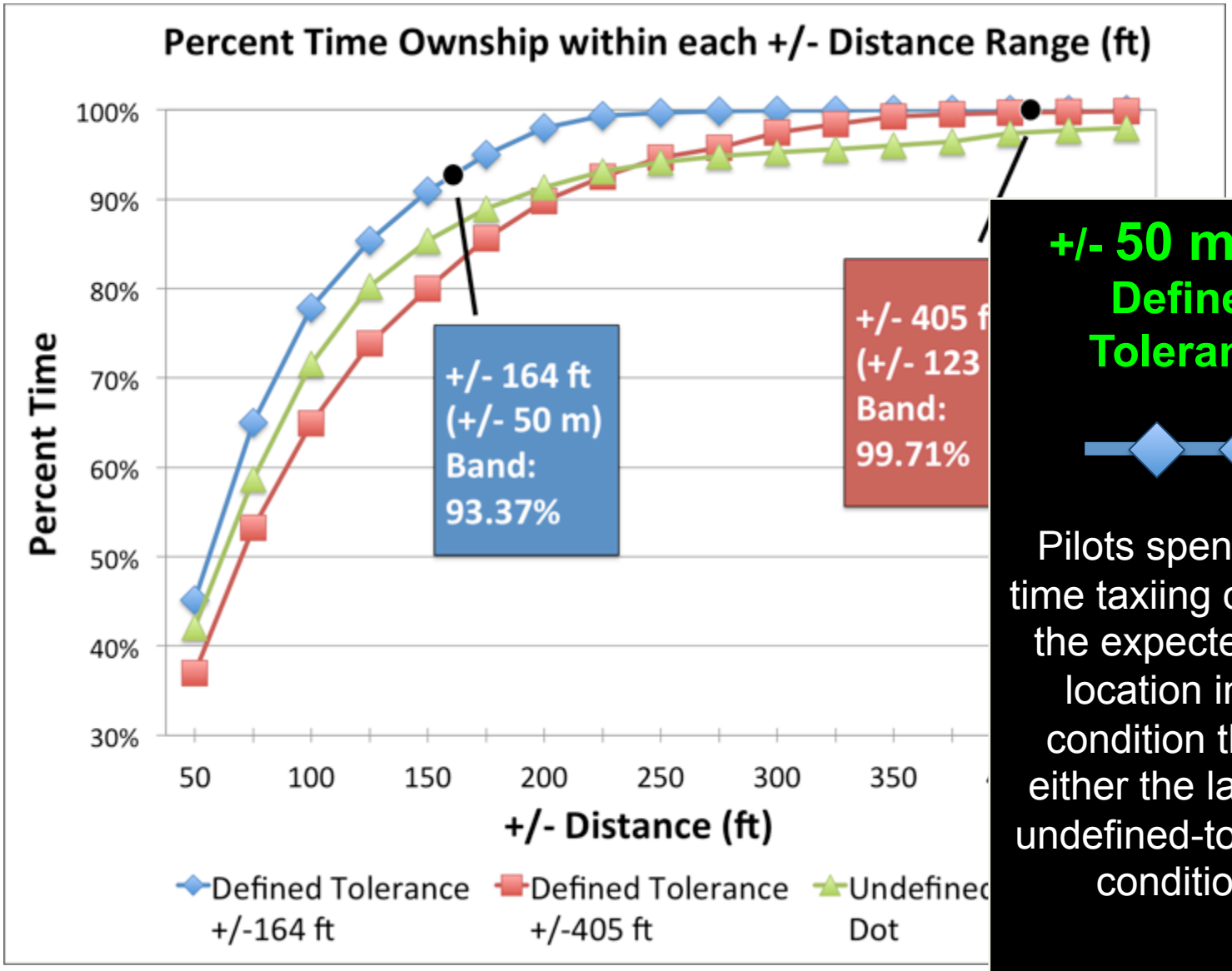
+/- 123 m 4DT Defined Tolerance

AMM augmented with graphical representation of *defined* allowable 4DT deviation

Flight Deck 4DT Display Comparison Study (2016)



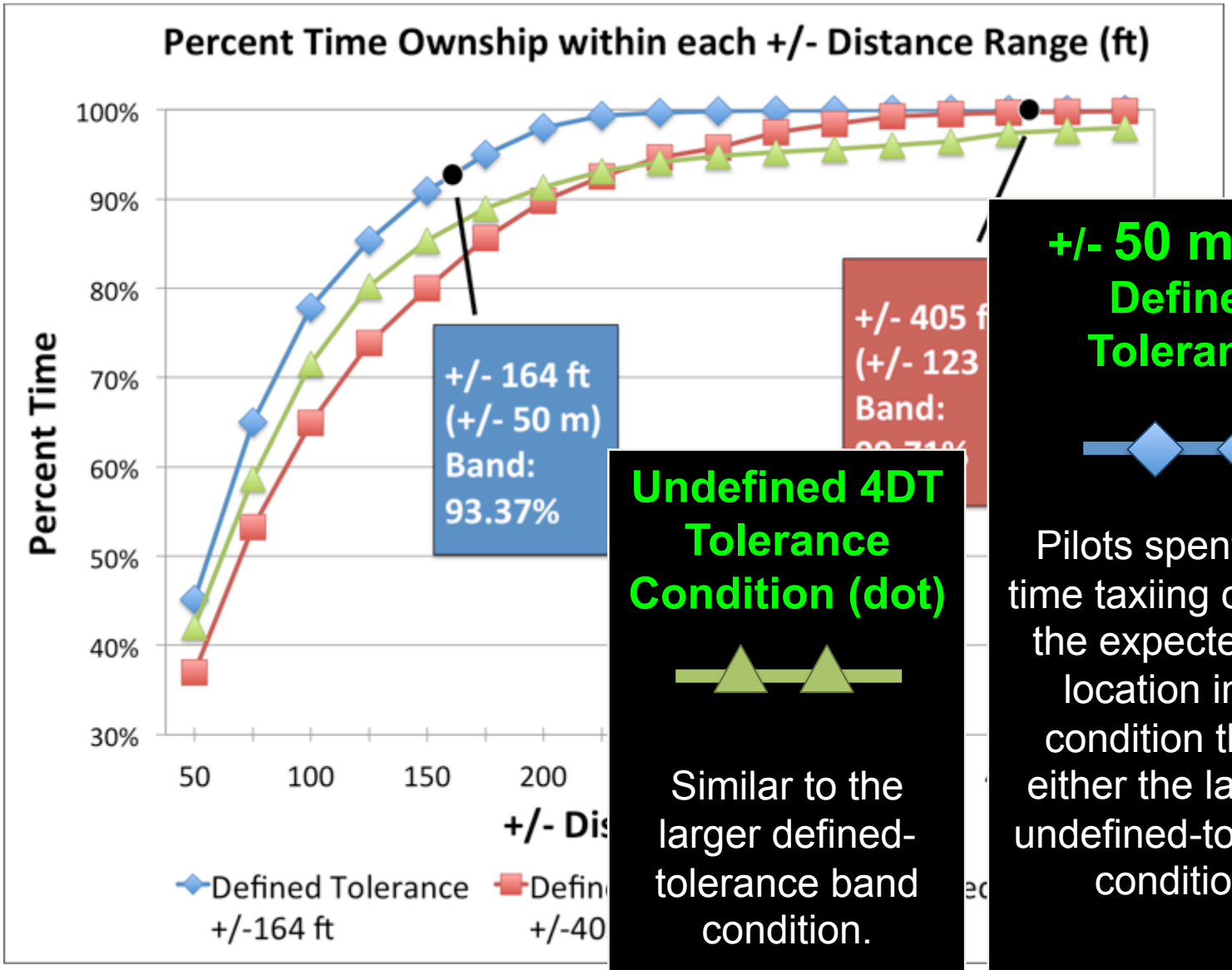
Flight Deck 4DT Display Comparison Study (2016)



+/- 50 m 4DT Defined Tolerance

Pilots spent more time taxiing closer to the expected 4DT location in this condition than in either the larger or undefined-tolerance conditions.

Flight Deck 4DT Display Comparison Study (2016)



Undefined 4DT Tolerance Condition (dot)

Similar to the larger defined-tolerance band condition.

+/- 50 m 4DT Defined Tolerance

Pilots spent more time taxiing closer to the expected 4DT location in this condition than in either the larger or undefined-tolerance conditions.

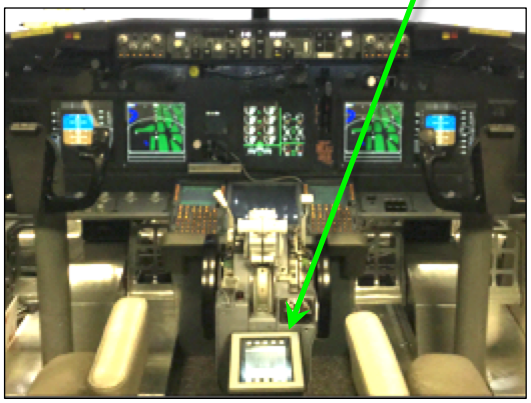
Backup Slides

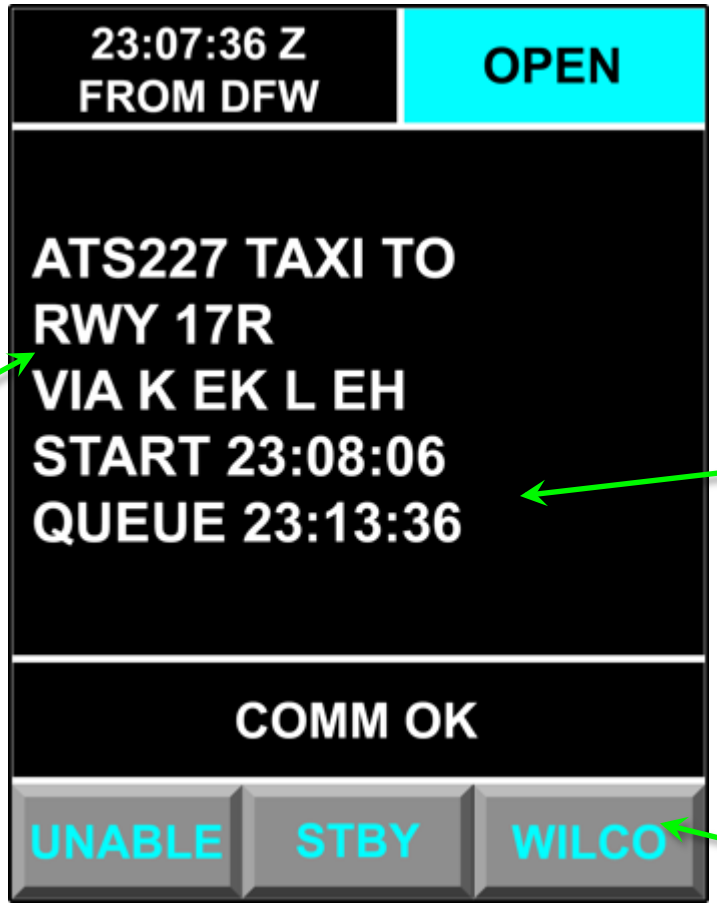
Flight Deck 4DT Proof-of-Concept Study (2014)

DataComm Touchscreen Interface Display

♫ DataComm Accompanied by Auditory Chime

Call Sign
RWY
Taxi Route



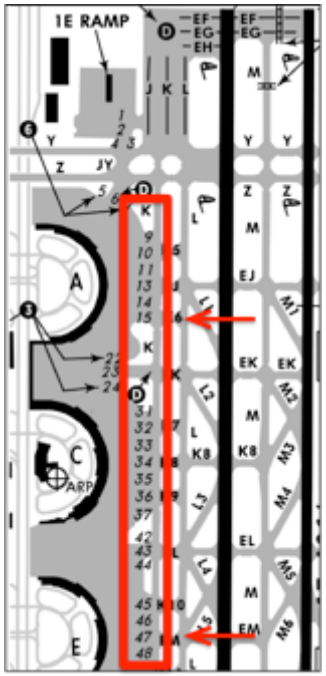


4DT Schedule Information

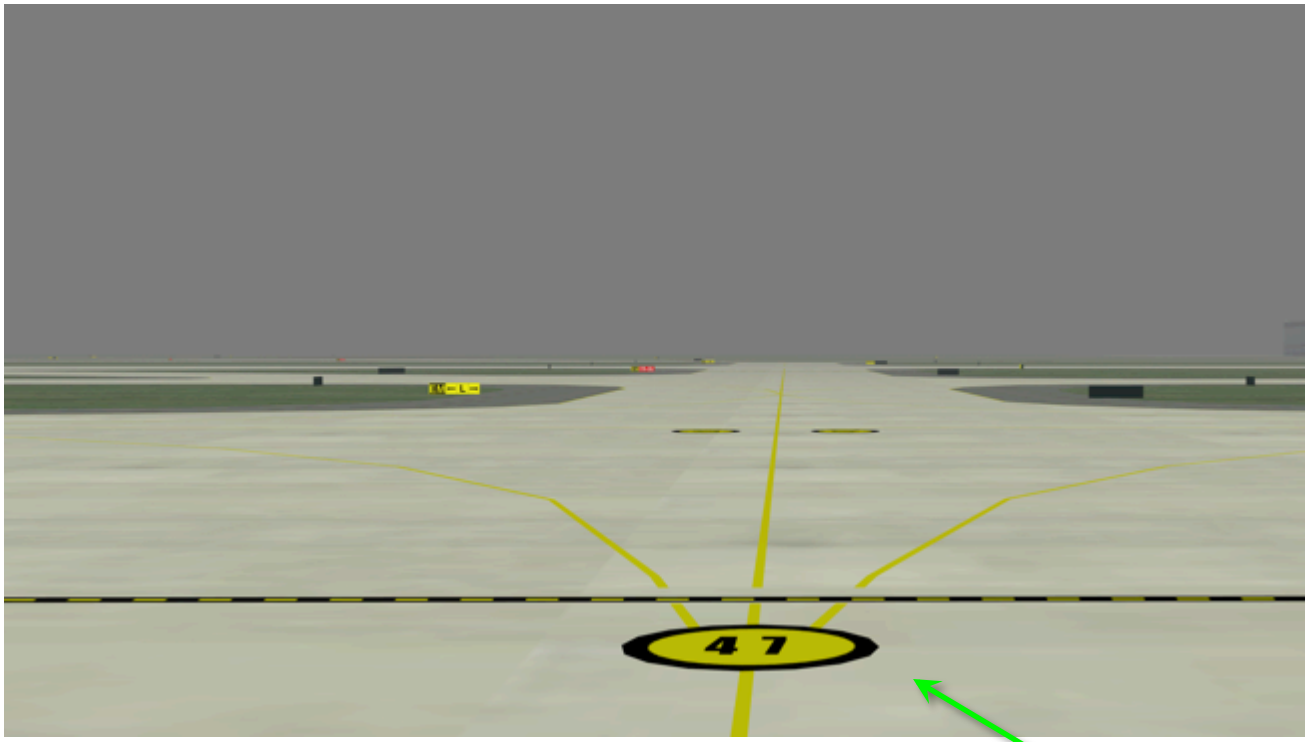
Touchscreen Response Buttons

(First Officer)

Flight Deck 4DT Proof-of-Concept Study (2014)



Out-the-Window (Ramp Departure Spots) at DFW

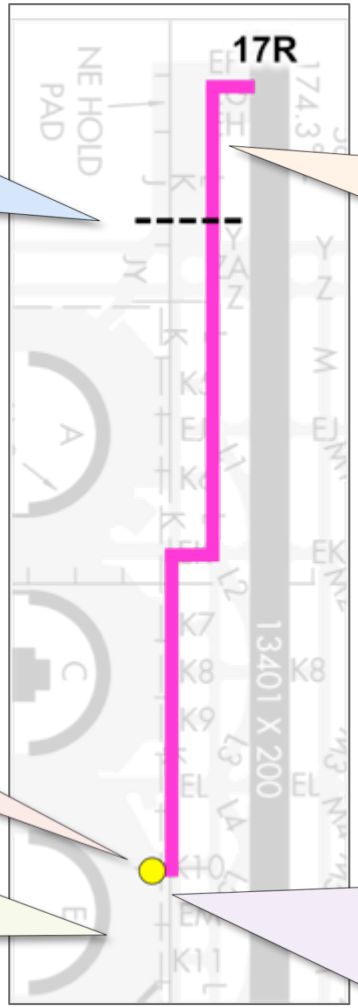


#'d Ramp Departure Spots

Flight Deck 4DT Proof-of-Concept Study (2014)

Queue Entry
4DT Indicator disappears.

Queue Area
Aircraft continues taxiing to RWY hold line.



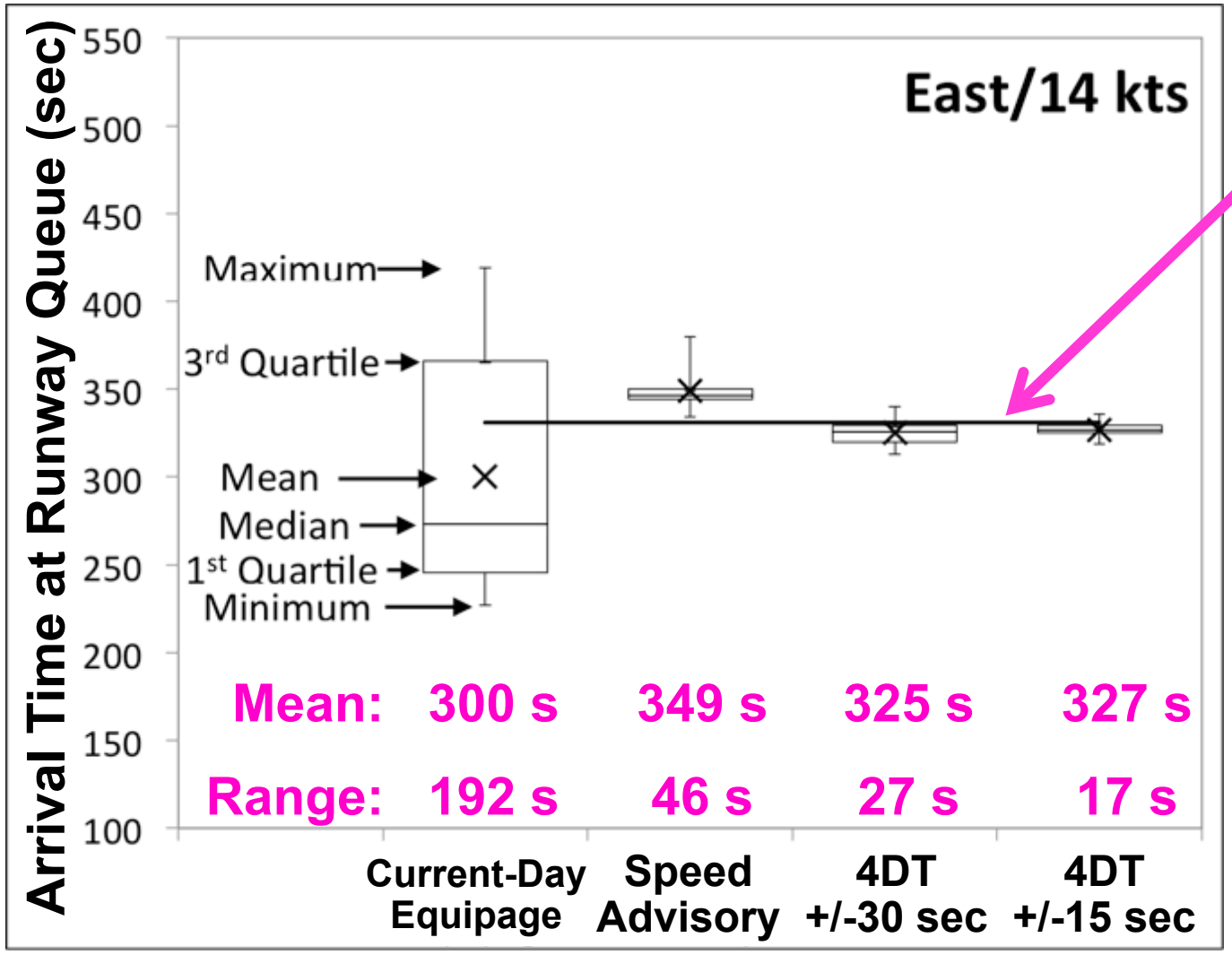
4DT Start Time
4DT Indicator begins to move. Pilot enters the AMA and begins taxi.

Taxi Clearance
At the spot, the flight deck receives the Taxi Clearance, via DataComm.

Pushback
Verbal clearance to pushback and taxi to Ramp Spot.

Flight Deck 4DT Proof-of-Concept Study (2014)

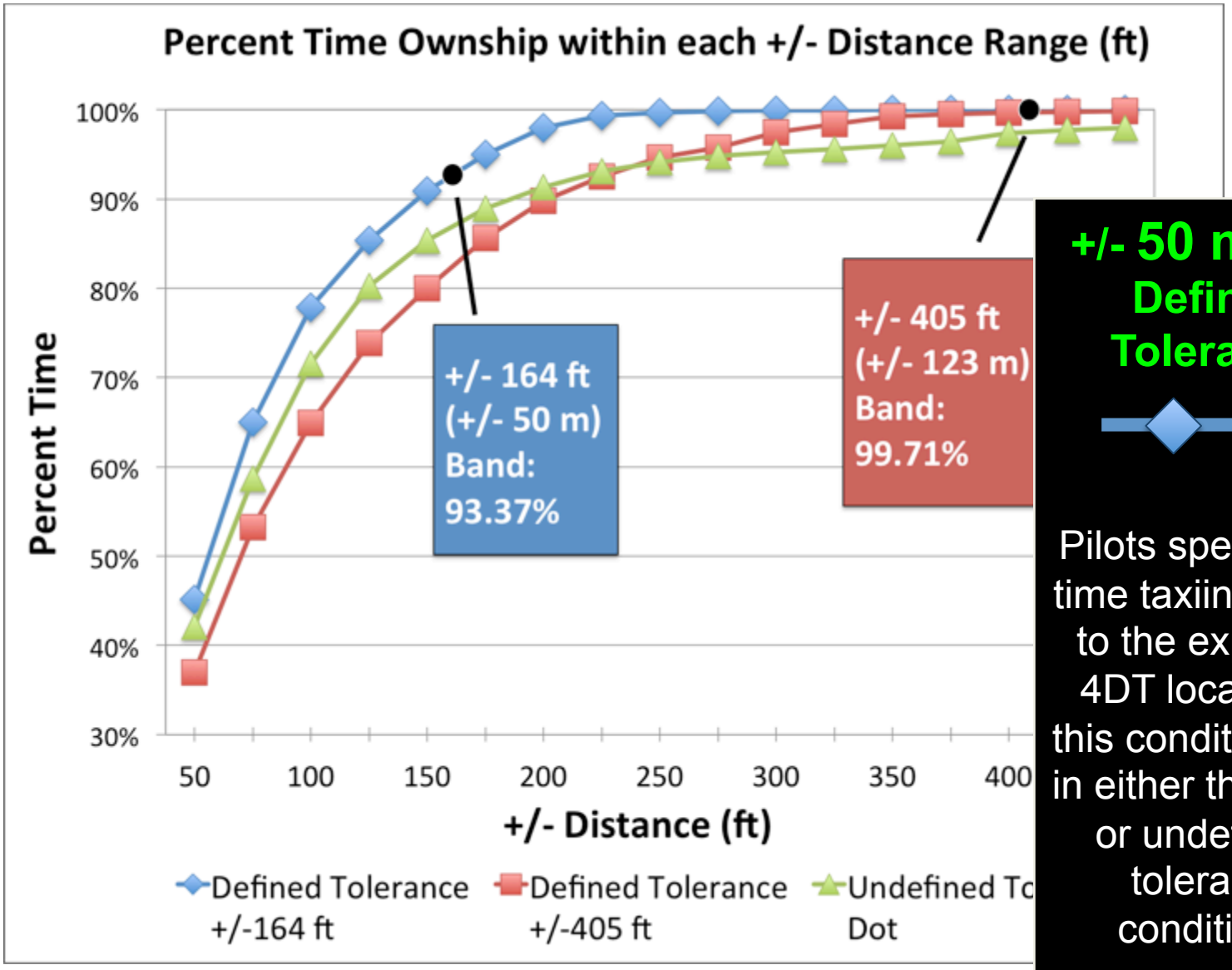
- Time of Arrival (TOA) variability at the queue-entry point (seconds).
- The TOA range was reduced by providing pilots a verbal speed in the Speed-Advisory condition, and further reduced in the two 4DT conditions.



331 sec Expected TOA at the Queue entrance, according to the Speed Profile.

Box and Whisker plots for the West1/15kts and West2/16kts routes followed a similar pattern.

Flight Deck 4DT Display Comparison Study (2016)



+/- 50 m 4DT Defined Tolerance

Pilots spent more time taxiing closer to the expected 4DT location in this condition than in either the larger or undefined-tolerance conditions.